Ecological and health impacts of heavy metals and PFAS leached by solar technologies into soils, water, air, and the food web at Brookside.

Executive summary

The long-term implications of siting a Utility Scale Solar Power (USSP) facility at Brookside are manifold but include:

- The unintended consequences of electromagnetic fields (EMF) in the vicinity of transmission lines on agricultural production, ecosystem health, and human health i(*see* EMF dossier, HSNO=6.7B, 9.3C, 9.4C).
- The loss of productive farmland with impacts on reduced balance of trade and increased current account deficits (*see* cost-benefit analysis).
- The risks of electrical discharge into flood waters for a USSP-facility sited on a flood plain (*see* hazards dossier).
- The risks of electrical discharge and toxic smoke in the event of a fire *(see* hazards dossier; HSNO = 4.1.2A).
- High rates of target organ toxicity, carcinogenicity, and e-waste within the life cycle of solar panels (*see* hazards).
- Solar technologies release leachates into soils through natural weathering by rain and UV light (e.g., delamination) and "pulsed" leachates onto soils by damaged panels (e.g., wind, lightening, hail, and fire).
- Leachates occur at landfills where they contaminate soils, water, air, and the food web. All panels must be recycled as per the 'Sustainability Act'.
- Leachates onto soils impact soil organisms and soil structure, reduce total organic carbon and total nitrogen in soils, change soil structure, and alter water dispersion (HSNO=9.2B)
- Leachates bioaccumulate in plants and animals where they impact both plant health and the health of animals that feed on those plants.
- Leachates (heavy metals, silica, and PFAS) will wash off site into aquatic systems and Lake Ellesmere where they are all toxic to fish and waterfowl. The 'forever chemicals' will then become an integral part of the aquatic food web at Te Waihora that includes ducks, eels and flounder harvested by local iwi. This is outside the provisions of the Food Act 1981 for maintaining healthy 'wild foods'.
- Leachates at the proposed Brookside USSP-facility over a 35-year period will progressively increase over time, and if there is a widespread fire or extreme weather events this then has the capacity to make Brookside a 'contaminated site'.
- At 'contaminated sites', offshore research on humans (Parvez *et al.* 2021) has demonstrated that heavy metals and polyfluoroalkyl substances (PFAS) bioaccumulate in organs that filter blood (liver, kidneys placentas) and these result in cancer, nephrotoxicity, hepatotoxicity, and toxic levels of metal halides and PFAS in blood. The placenta in all studies were most affected (toxic levels are 5x those at other sites).
- Babies with elevated metal halides and PFAS in the blood are born with poor AGPAR scores, poor physical attributes (height, head circumference, chest circumference, BMI), and poor states of cognition because heavy metals (Pb, Cd, Ni, Al, and Ag) and PFAS from the electronics industry have passed through the placenta into the unborn foetus.
- The offspring of all other species (terrestrial vertebrates, birds, and even fish) are similarly affected. Bird shells are thinner, hatchlings struggle, fewer hatchlings are fledged. Heavy metals and PFAS have found their way into the plethora of wild animals in Africa, with offspring struggling because of contaminants.
- At contaminated sites, the food webs within ecosystems are affected by reduced fertility, reduced survivorship of young, and reduced animal welfare for all species; invertebrates, terrestrial vertebrates, and aquatic organisms.
- PFAS, metal halides, and silica bioaccumulate in the gills, livers, kidneys, and meat of fish where they induce toxic effects and cause secondary poisoning risks to humans.
- In summary, the development of a USSP facility at Brookside is an enterprise thwart with uncontrollable risks, political shortcomings, economic and fiscal shortcomings, regulatory shortcomings, environmental shortcomings, and shortcomings for the health and welfare of the Brookside community.

Introduction:

Leachates from equipment used at Utility Scale Solar Power (USSP) facilities are predominantly metal halides with a complement of per- and poly-fluoroalkyl substances (PFAS). These form part of a group of compounds colloquially referred to as 'forever chemicals'. They get into the food web and/or water supplies and persist from one trophic level to another, until they are eventually ingested as water contaminants or food contaminants by apex predators, including man (Fig. 1). The half-lives of PFAS in man are >5.4 years, the half-life of lead (Pb^{2+}) as one of many heavy metals in solar farms is ≈ 1 year in children, and the half-life of cadmium in livers is >10 years. They are persistent and pervasive chemicals that are an intrinsic part of solar technologies.

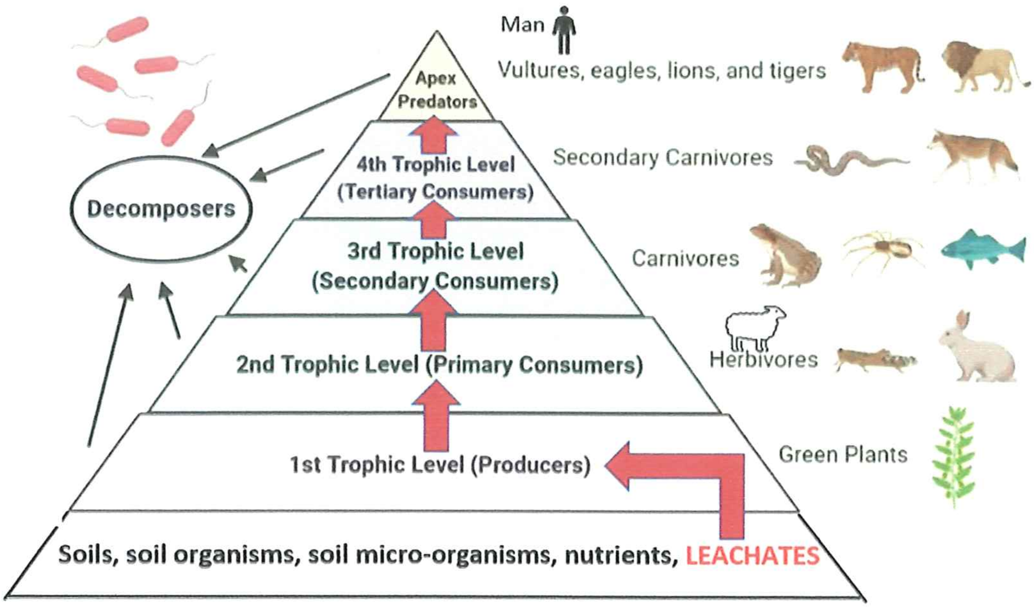


Figure 1. Illustration of how 'forever chemicals' persist in the food chain affecting each trophic level.

At each trophic level 'forever chemicals' affect the health and welfare of organisms:

1. Excess metal halides kill soil organisms, change soil pH, change total organic carbon and total nitrogen in soils, change soil aggregation, change flocculation, form clods, and change water dispersion.
2. Metal halides and particularly metal iodides impede plant growth, suppress enzyme reactions (e.g., activity of soil mycorrhizae that fix nitrogen), kill some plants, and bioaccumulate in the roots, stems, and leaves of plants (1st trophic level).
3. When plants, berries, and fruits are consumed by herbivores, insects, birds, or man; then the metal halides and PFAS in them bioaccumulate in the livers, kidneys, brain, placentas, and other organs of primary consumers causing issues with animal welfare, fertility, and target organ toxicity (2nd trophic level).
4. Secondary consumers that eat insects, small terrestrial vertebrates, and the carrion of dead animals (e.g., fish) then ingest the metal halides and their health is affected (3rd trophic level).
5. Scavengers (e.g., gulls) and carnivores that feed on meat then ingest heavy metal and PFAS residues in livers, kidneys, etc and bioaccumulate these 'forever chemicals' in tissue (4th trophic level).
6. Finally, apex predators (e.g., raptors, carnivores, man) at the top of the food chain bioaccumulate residues either from the water they drink or fruits, berries, vegetables, and meat they eat.

New Zealand unfortunately has a history of high metal halides in food following the import of superphosphate from Nauru. Superphosphate on the island accumulated as seabird guano over millions of years. Unfortunately, fish bioaccumulate cadmium from the oceans, and then when those fish are consumed by seabirds that forms part of the guano that was then exported as superphosphate to New Zealand. Superphosphate has been broadcast onto pasture; so, cadmium levels in Waikato soils have progressively increased until they exceeded international guidelines (Fig. 2). Animals grazing these pastures have bioaccumulated cadmium (Fig. 3) to the stage where the livers and kidneys of New Zealand livestock exceeded international standards for cadmium and were no longer able to be exported. High cadmium levels of course affect not only animal health (sheep and cattle), but the health of humans that eat the livers, kidneys, hearts, sweetbreads, and the brains of livestock.

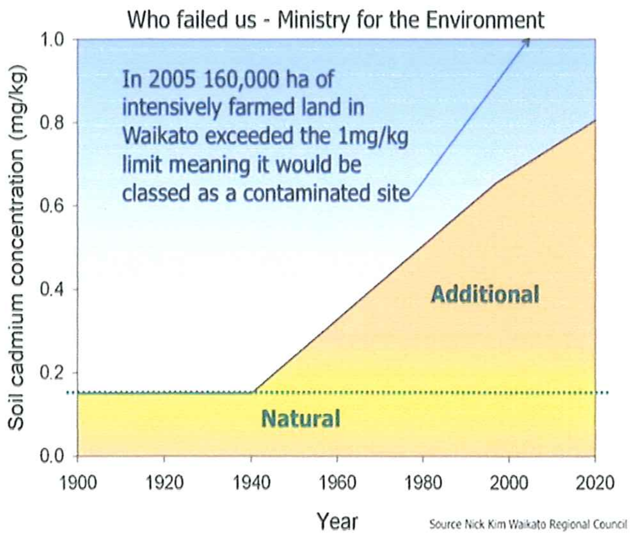


Figure 2. Cadmium levels in soils in the Waikato.

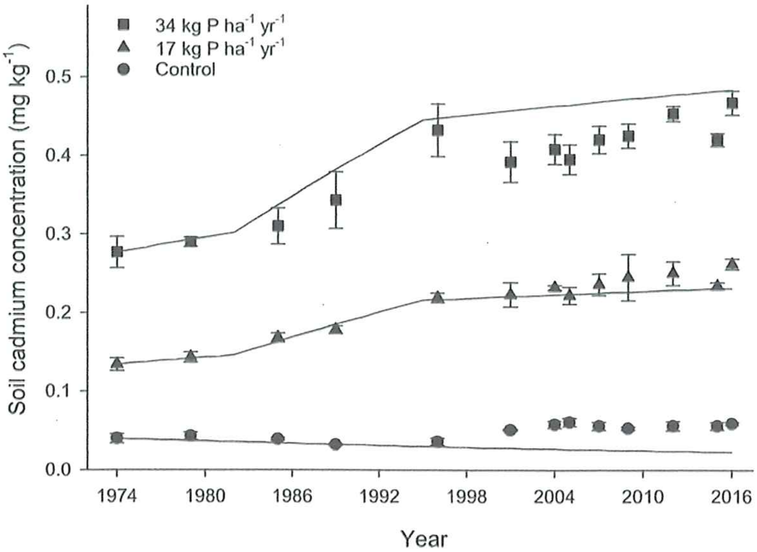


Figure 3. Cadmium levels in livers of stock grazed on soils fertilized with 0, 17, and 34 kg/ha/yr of superphosphate.

The 2nd example I will give that currently affects residents at Brookside is the one of nitrates in water. With increased application of nitrogenous fertilizers on farms following increased numbers of dairy cows (Fig. 4), then nitrates in water have progressively increased (Fig. 5). The health effects of higher nitrates are multi-factorial, but the number of premature births has increased by 47% during the first 22 years of the new century, birth defects have increased (e.g., neural tube defects, cleft palate), bowel cancer has increased, etcetera.

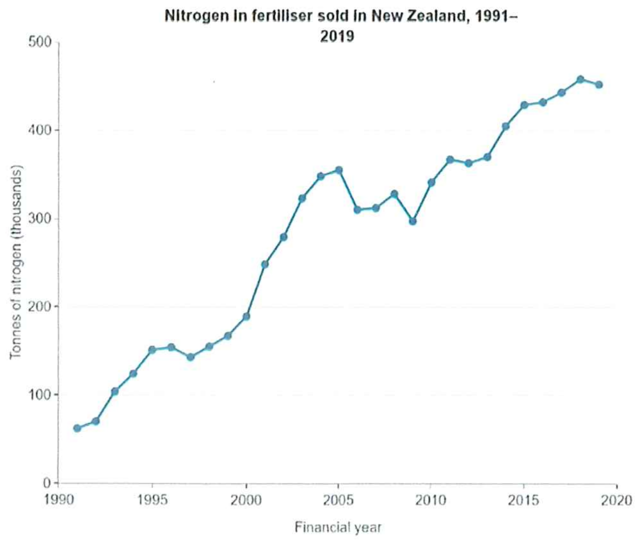


Figure 4. Nitrate application to pastures in NZ.

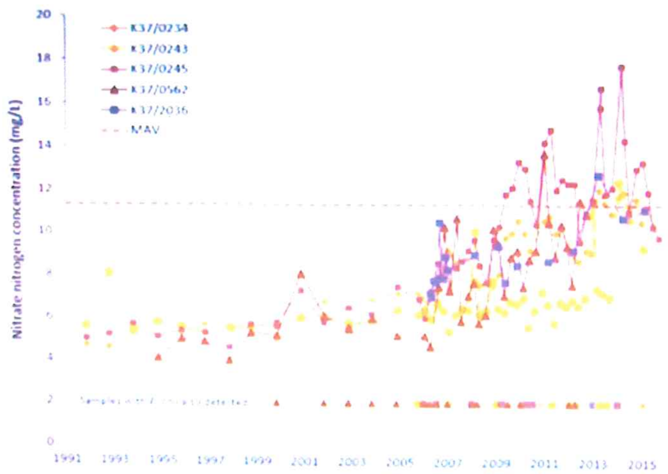


Figure 5. Nitrate-nitrogen concentration in Mid-Canterbury wells

New Zealand politicians have not learned the lesson from the cadmium/superphosphate debacle, nor the lessons from the debacle of nitrates in wells, and are now planning to distribute 'forever chemicals' in the form of metal halides and PFAS from solar technologies onto pastures throughout New Zealand. To be fair the views on the parliamentary grounds are somewhat polarized: on one side there exists the Commissioner for the Environment (Simon Upton) who wants to minimize heavy metal and PSAF pollution (*see* 'Knowing what's out there: regulating the environmental fate of chemicals' in his 2022 PCE Report); on the other side of parliamentary grounds there are the 'Greens' who want to cover the country with solar farms that are made entirely of heavy metals, PFAS and silica that leach kilogram after kilogram of 'forever chemicals' into the environment each year. New Zealand is effectively trading high carbon emissions for high emissions of 'forever chemicals' into the environment.

Solar energy and USSP facilities are now "national policy". That fact is used to justify many things that are in conflict with the intent of the RMA act. The national policy statement that was provided by the developer within the applicants RMA application is testamount to this. Institutions like ECan and SDC follow "national policy" directives without examining the risks of contaminants. Once it is "policy" then people stop thinking about the 'risks' that are part of the RMA. Just as in the case of cadmium and the pervasive nitrates within Canterbury groundwater, the 'forever chemicals' from electrical equipment will progressively accumulate in soils turning good farmland into soils with contaminants, and the leachates from these contaminated soils will eventually occur in both groundwater and food (fruit, vegetables and meat). It is what has happened offshore under solar panels and with e-waste in landfills in particular; and it is what will happen in New Zealand. There have been a multitude of science papers written in the last 2 years warning about the risks associated with heavy metals and PFAS (Purchase *et al.* 2020, Kwak *et al.* 2020, Zhang *et al.* 2023, Panthi *et al.* 2021, Nain *et al.* 2021, Calvert *et al.* 2015, Abbassi *et al.* 2020, MoE 2018, etc.) and the leaching of heavy metals into the environment (Saha *et al.* 2021). In 2023, Zhang wrote a paper entitled "Green or Not"; possibly because he has been around solar technologies for so long he understands the shortcomings of increased heavy metals in the food web. One of the unfortunate aspects of USSP facilities with their arrays of solar panels, inverters, transformers, lithium-ion batteries, and cabling is that every piece of equipment is comprised of "forever chemicals". On a "solar farm" there are literally thousands of tonnes of these chemicals that progressively shed layer after layer of chemical compounds onto soils and into the food web as equipment either gets damaged and/or naturally weathers. Solar equipment disposed of at landfills is a worst-case scenario and creates a major source of leachates. This dossier evaluates whether these effects are "<u>minor</u>" as the applicant states for his proposed USSP-facility at Brookside, or whether the implications pose a serious long-term impediment to New Zealand's primary exports, the environment, animal welfare, and the health and wellbeing of people.

Hazards in Solar Technologies

There are a multitude of different materials used in solar technologies to manufacture panels, within framing, within inverters, within transformers, within cabling and within batteries. The main ones that have been detected as important leachates are shown in Table 1 below as a comparison with brodifacoum (as another long-lived material.

Table 1. The half-lives, health, and environmental risks of materials used in solar technologies.

Chemical	Metal half-life Liver (d)	Aquatic toxicity 9.1	Soil toxicity 9.2	Terrest. Vert. 9.3	Toxic 6.1	Muta 6.6	Carcin 6.7	Reprod 6.8	Target Organs 6.9
Brodifacoum	114.6	9.1D	n/t		6.1E				6.9B
Aluminium	150 in liver; 7years brain	9.1A, pH	9.2B		6.1E				6.9B
Lead	36 blood 130 liver 2 years brain	9.1A	9.2B	9.3A	6.1C	6.6B	6.7B	6.8A	6.9A
Silica		9.1B							6.9A
Cadmium	4 -19 yrs	9.1B			6.1C		6.7A	6.8B	6.9A
copper	21 d 435 d brain	9.1A	9.2D	9.3B	6.1B	6.6A			6.9B
Nickel	35 d	9.1B		9.3B	6.1C		6.7A		
Zinc	245 d	9.1A		9.3C	6.1D				6.9B
Silver	50d	9.1A	9.2B	9.3A	6.1C			6.8B	6.9A
Arsenic	10 hrs	9.1A	9.2B	9.3B	6.1C		6.7A		6.9A
Chromium	9 d	9.1A	9.2B	9.3B	6.1A	6.6A	6.7A	6.8A	6.9A
Selenium	150d	9.1C	9.2C		6.6B	6.6B			6.9B
Lithium	1-2d	9.1D	9.2D		6.1D				
Strontium	50.5 d	9.1C	9.2D		6.1D				
Titanium	12.7 d	9.1B			6.1E		6.7B	6.8B	
PFAS	5.5 – 8.5 yrs	9.1A & B	9.2C	9.3B	6.1C			6.8A	6.9B

What does this table tell us about the inherent hazards in solar technologies? Some issues are:

- all materials leached from panels are very hazardous in the aquatic environment (mainly 9.1A - 9.1B HSNOs);
- almost all leached materials are hazardous to soil micro-organisms (mainly 9.2B to 9.2C);
- almost all leached materials are toxic if ingested (mainly 6.1B to 6.1D);
- once ingested those materials cause target organ toxicity (6.9A to 6.9B);
- many materials in solar technologies are carcinogens, mutagens, and teratogens; and,
- most heavy metals and all PFAS have a long half-life in the liver or brain, so they bioaccumulate in tissues, and people that ingest them are sick for a long time.

In short, the 'hazards' within solar technologies are very high. Therefore, in the model 'Risk=Hazard x Exposure' the only way we can keep the environment safe, and people safe is to ensure 'Exposure' is negligible. The rest of this report focuses on sources of exposure, impacts of those exposures on ecosystems, and impacts on health.

Leachates

All studies (including the 20 cited in this report) demonstrate solar panels and other equipment at USSP-facilities leak metal halides and PFAS as they deteriorate during weather events, exposure to UV light, and through fire. Various reports have speculated on whether rates of leakage differ through time, differ with environmental factors (e.g., acid rains) and because of different weather conditions (extremes of heat or freeze-thaw processes) or intense UV action that slowly degrades ARC (anti-reflective) and ASC (anti-soil) coatings. However, there is not enough detail in the literature to know quantitatively whether the amount of material that falls off panels are any different in the long term (see Fig. 6), and/or whether perceived differences are a by-product of testing procedures and the age of the equipment. To look at the data presented in published research within a small window of time and say this equipment is better than that belies the fact that to date there have been no longitudinal studies done on any piece of equipment. The plethora of recent reports and published papers during 2020, 2021, 2022 on better ways to encapsulate components (see references in the 'hazards' dossier) are a testament to the fact that manufacturers recognize leachates from solar technologies are an ongoing problem that they are trying to remedy. At this moment in time no equipment is environmentally safe. Clearly, damaged cells, cells that are delaminating, and solar panels with weak spots leach their contents inordinately faster than intact panels (Nover *et al.* 2017, 2021, 2022)

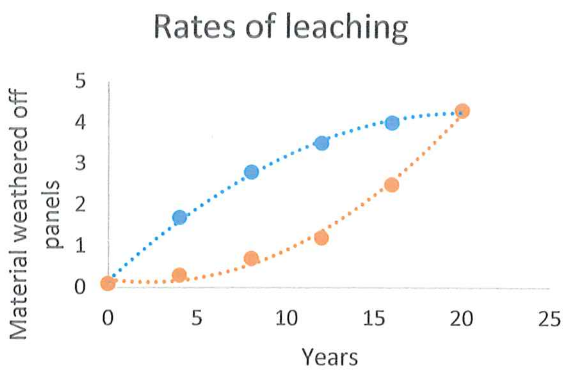


Figure 6. Rates of leaching of metal halides in equipment can vary through time.

What is unequivocal is metal halides and silica from solar panels and PFAS from circuit boards, electrical insulation and solar panels are deposited on soils. What is also unequivocal is that solar panels and other electronic equipment placed in landfills leak huge volumes of hazardous material into water and surrounding soils. USSP-facilities could potentially become the largest repository of manufactured heavy metals and PFAS (i.e., 'forever chemicals') within the New Zealand environment. Internationally, these materials currently debilitate or cause the premature deaths of hundreds of thousands of people each year (*see* Parvez *et al.* 2021), with infants and children the most vulnerable. Where will the planet be in 2-3 decades with this so-called "green technology"? Furthermore, leachates of e-waste have been demonstrated to permeate every ecosystem on Earth, debilitating or killing billions and billions of micro-organisms, invertebrates, mammals, reptiles, birds, and in particular aquatic organisms each year. Is humanity taking a giant leap forward with solar power, or is it making yet another cataclysmic mistake that could cast an even bigger pall of despondency over the next generation than unwanted carbon emissions?

As an old scientist I am not going to speculate on what might or might not eventuate, just present the empirical data that is currently available (all referenced of course) and let the reader decide. Furthermore, I want to demonstrate the unnecessary exposure to 'risks' (i.e., 'hazards' x 'exposure') for health, the risks to food and water, and the risks to fauna and flora (i.e., environmental risks), and the risks that the community at Brookside will be exposed to by a USSP-facility in their neighbourhood.

There is a growing research effort dedicated to understanding the leakage of Pb^{2+} and other metal halides from solar panels in the presence of moisture, acid rain, panels damaged by wind and hail, the effects of UV fields, and the effects of extremes of heat and cold. Su et al. evaluated the leaching concentration of Pb^{2+} from solar panels and found that the amount of Pb^{2+} exceeded the hazardous waste limit of 5 mg L^{-1}, and Pb^{2+} was found to continuously leach out in the leaching cycles of water extraction. Hailegnaw et al. reported 72% loss of Pb from

$CH_3NH_3PbI_3$ perovskite films after exposure to simulated rainwater (pH 4.2), and the leached Pb species include both soluble Pb^{2+} and PbI_2 solid or colloids. Yu et al. studied the Pb^{2+} leaching from $MAPbI_3$, $FA_{0.85}MA_{0.15}Pb(I_{0.85}Br_{0.15})_3$ and $Cs_x(MA_{0.17}FA_{0.83})_{(100-x)}Pb(I_{0.83}Br_{0.17})_3$ from PSCs under simulated normal (pH = 5.6) and acidic (pH = 4.5) rainwater. The concentration of Pb^{2+} first increased to 0.7 and ≈1.7 mmol L^{-1} in normal rain and acidic rain, respectively, and all gradually reached 2–2.7 mmol L^{-1} after 1 day of leaching. Panthi et al. examined that the concentration of leached Pb^{2+} in $MAPbI_3$ was as high as 6.6 mg L^{-1} through the toxic characteristic leaching method (pH 4.93). Wan et al. observed that Pb leaching ratios of encapsulated and unencapsulated $MAPbI_3$ modules were 2.41% and 100%, respectively, when broken PMs were washed by rainwater (pH = 5.6) at 85 ºC for more than 4 h. Jiang et al. reported that Pb in $Cs_{0.07}FA_{0.93}PbI_3$ films leached out entirely at 0.54 g m^{-2} from damaged solar panels when exposed to simulated heavy rain for 72 h. It is thus clear that Pb^{2+} could easily leak out of solar panels in the case of physical damage, failure of encapsulation, or exposure to heavy rain.

Silver (Ag) used in electrodes and solar panels was leached from damaged solar panels at maximum daily rates of 127 µg/L and 181 µg/L in panels delaminating in the weather (Epinosa *et al.* 2016). Zinc was leached at 665 µg/L on one day from damaged panels.

The amounts of Se in soils under a silicon USSP over 4-5 years increased by 97% to 0.57 µg/g, lithium in soils increased 386%, strontium 86%, nickel 37% and barium 61% (Robinson *et al.* 2017). Because these were relatively new panels that have not begun degrading, we do not know how much will be under these panels in 25 years' time.

Within a year, 1.4% of lead, 61% of cadmium as well as other heavy metals (e.g., selenium) had leached out of solar panels in laboratory conditions (Nover *et al.* 2017).

The long-term consequences for ecosystems on solar farms has yet to be fully assessed. A 2023 publication entitled "Green or Not?", Zhang *et al.* states that the environmental impacts remain unknown, and improvements to the technology are still required to improve its sustainability. In his 2021 publication, Kwak *et al.* indicates that despite ongoing work to prevent leaching that "environmental risks remain a serious outstanding issue". These are people that live and breathe solar technologies; yet they have real concerns about its future.

There has been no meta-analysis of increased heavy metals and PFAS in soils around solar panels that I can find. However, in countries like China where increased heavy metals from industry are impacting human health, research has collated data on rising levels of heavy metals in water. At Brookside soils are wet for long periods over winter with extensive leaching of nitrates into water. The leaching of metal halides and PFAS into groundwater will also occur in wet soils.

The other major source of electronic leachates is landfills (Rajesh *et al.* 2022, Saha *et al.* 2021, Purchase *et al.* 2020, Emmanuel *et al.* 2022, Epssien *et al.* 2022, Espinosa *et al.* 2016). The literature indicates leachates of electronic equipment at landfills enter groundwater (Table 2) and become part of the food web. Of course, there are sources of heavy metals other than electronics, so it becomes difficult to apportion risk. In China soil contamination with heavy metals (Cd, Cu, Pb, Zn, Hg, etc) is ubiquitous (Wen *et al.* 2022), with those materials now at such high levels in foods, that the health effects on people are pervasive (Parvez *et al.* 2022). The government of China currently spends $27 billion annually attempting to remediate soils; but here in New Zealand we just want to rush headlong into further contamination of good soils with ever-increasing amounts of leachates from solar farms.

Table 2. Leachates from electronic and industrial waste placed in landfills.

'Forever chemical'	Location	Residues in soils (mg/kg)	Residues in air mg/m^3	Residues in water near landfills (mg/L)	Residues in soils <1km from landfill (mg/kg)
Pb	India	2645	160		223
	China	4500			320
	China	2570			
	Ghana	1685	0.98		
	Nigeria (6 sites)	9623		3.0	
Cu	India	6734		>31.2 (ponds)	684
	China	11,140			590
	China	4820			
	Ghana	2260	1.2		
	Nigeria	7106			
Zinc	India	776			573
	China	3690			298
	China	1260			900
	Ghana	2435			
	Nigeria	8178		23.88	
Hg	Nigeria (6 sites)				
Ag	Denmark	852			
Cadmium	China	17.1	5.7		1.4
	China	10.7			0.22
	Nigeria			7.12	
Aluminium	Ghana		6.5		
Arsenic	Nigeria (6 sites)			0.35	
Chromium	Nigeria (6 sites)			1.50	
Nickel	Nigeria (6 sites)			2.42	
PFAS	China	726	49.9		
	India	551	35		
	India	362	488 (dust)		

A review of just some landfill sites globally demonstrates heavy metals at these locations vastly exceed international standards for contaminants (Table 3.). These contaminants are finding their way into both groundwater and surface waters.

As an aside, the Selwyn District Council originally proposed a landfill in the Hororata / Darfield area where the public were opposed to the prospects of leachates in groundwater. In the face of significant community pressure, the council eventually decided against the original site and supported the Kate Valley site due to its location. Given the problem with leachates at the Brookside site and run-off of these materials down into Lake Ellesmere, maybe it is an opportune time for the applicant and Selwyn District Council to look at an alternative location for their USSP-facility on unproductive land.

Table 2. Metal(loid)s as contaminants detected in e-waste sites that exceed national guidelines (Abassi *et al.* 2020).

Country and location	Environmental matrix	Pollutants detected	Levels
China: Taizhou	Soil	Cu, Cr, Cd, Pb, Zn, Hg, and As	0.37 to 1.2 mg kg^{-1}
China: Longtang	Soil	Cd, Cu, Pb, and Zn	GM of 17.1, 11,140, 4500, 3690 mg kg^{-1} respectively
China: Longtang	Soil	Cd	Higher than 0.39 mg kg^{-1}
	Ponds and	Cu	Higher than 31.17 mol L^{-1}
	Well water	Cd, Cr, Cu, Mn, Ni.	All significantly above the national guideline level
China: Guiyu	Soil	Ni, Cu, Zn, Cd, Sn, Sb and Pb	GM of 278.4, 684.1, 572.8, 1.36, 3472, 1706, and 222.8 mg kg^{-1}, respectively
China, Guiyu	Sediment	Cu, Zn, Cd, Sn, Sb and Pb in the sediments	Mean of 4820, 1260, 10.7, 2660, 5690 and 2570 mg kg^{-1}, respectively
China, Guiyu	Road dust	Cd, Cr, Mn, Pb	Mean of 1.94, 69.71 and 693.74 and 589.74 mg kg^{-1}, respectively. Cd and Pb was 4.10 and 3.18 times higher than the reference area
China: Guiyu	Surface dust	Pb, Cu, Zn and Ni in workshop	GM of 110000, 8360, 4420 and 1500 mg kg^{-1}, respectively
		Pb, Cu, Zn and Ni in adjacent road	22,600, 6170, 2370 and 304 mg kg^{-1}, respectively
China: Guiyu	Ambient air	Pb and Cd	GM of 160 and 5.7 mg m^{-3}
		PM2.5	49.9 μg m^{-3}
China: southern rural region	Groundwater	Cd, Pb, Zn, Cu, and Ni	Between 1.3 and 140 times higher than the national guideline values
China: Guangdong	Soil	Cu, Zn, Pb, Ni, Cr, and Cd	GM of 590, 298, 320, 7,1, 19.7, and 0.22 mg kg^{-1}, respectively
India: New Delhi	Surface dust* (battery workshop),	Cd Cr, Cu, and Hg	Up to 200,000, 103, 6850, 362,000, 460, and 4920 mg kg^{-1}, respectively
Philippines: Manila	Surface soil	Cd, Co, Cu, Mn, Ni, Pb and Zn	GM of 2.5, 30, 680, 950, 47, 800, and 900 mg kg^{-1}, respectively
	Surface dust	Cd, Co, Cu, Mn, Ni, Pb and Zn	GM of 3.9, 33, 6300, 1800, 380, 800, and 2900 mg kg^{-1}, respectively
Vietnam: Bui Dau village	Soil	Cu and Pb	The highest values recorded were 3000 and 2200 mg kg^{-1}, respectively
Ghana: Agbogbloshie	Surface soil, Soil	Cd, Co, Cr, Cu, Fe, Mn, Ni, and Zn	GM of 0.24, 1.01, 2.35, 54.4, 124, 35.4, and 19.2 mg kg^{-1}, respectively
		Cu, Zn, As, Cd, Sn, Sb, and Pb	GM 602, 1274, 6.69, 1.51, 33.3 36.6, and 442 mg kg^{-1}, respectively
Ghana: Agbogbloshie	Ambient air	Al, Cu, Fe and Pb	The highest values recorded were 6.5, 1.2, 8.9, 0.98 mg m-3, respectively
Ghana: Korle Lagoon	Sediment	Cu, Pb, and Zn	Up to 2260, 1685, and 2425 mg kg^{-1}, respectively
Nigeria: Lagos	Soil	Cu, Pb, and Zn	329 to 7106 mg kg^{-1}, 115 to 9623 mg kg^{-1}, and 508 to 8178 mg kg^{-1}, respect
Nigeria: Lagos, Aba, Ibadan	Surface dust	Significant high levels of As, Cd, Cr, Cu, Hg, Pb, and Sb.	Mean metal concentration at the e-waste recycling sites exceeded the Nigerian standard guideline values by 100 to 1000 s times

The concentrates of heavy metals in groundwaters from randomly located wells varied seasonally in response to changed mobility of substances during wet and dry seasons, and the abundance of residues from industry (Zhai *et al.* 2022). In NE China the primary source of Co, Cr, Pb and Ni in wells are from industry, with sources of Cd split equally between industry and agriculture. However, many of the main pollutants in Chinese groundwater can be routed back to the electronics industry. In India (Ahmed *et al.* 2022) the most problematical metal was lead (Pb) with its recent proliferation in groundwater once again routed back to industry; in Pakistan the most problematical heavy metals are Pb and Cr; and in Nigeria Pb, Cd, and Hg are all serious health risks. At all locations heavy metal contaminants exceed WHO limits for health (Table 3), with most recent increases of heavy metals in drinking water sourced back to the electronics industry (either manufacture or waste disposal). Solar technologies either made by industry or deployed as USSP-facilities inevitably contribute to this malaise of water contamination.

Measured PFAS in groundwater depend on their solubility and the rates that leachates are applied to soils. PFAS with only 4 carbon atoms are more soluble than compounds with >5 carbon atoms (McMahon *et al.* 2022). From 254 wells in the eastern USA, PFAS were detected at worrying concentrations in 60% of public sources of drinking water.

The PFAS leached out of solar panels, electrical cables, and circuit boards onto soils at USSP facilities are a factor in water contamination and will eventually get into the bores belonging to Brookside residents. How serious are the implications? PFAS impact the health of babies and infants especially (see section on 'Health' below, and the voluminous NZ 'MoE' publication on PFAS).

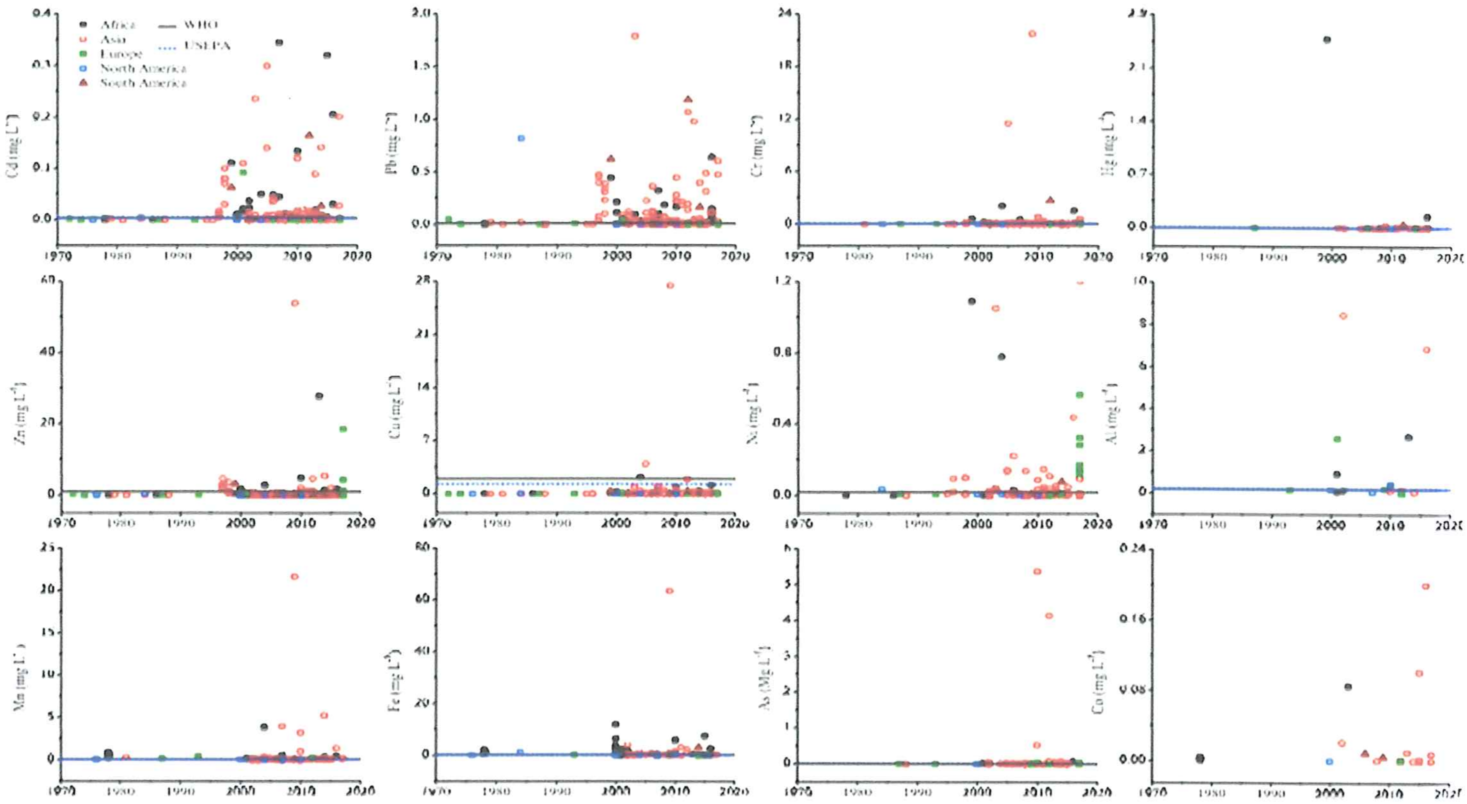
There can be little doubt that electronic industries and discarded electrical appliances distribute e-waste far and wide in every nation, and those industries that support the production of electronic devices are a major source of water contamination at landfills. Heavy metals contaminating soils, plants, meat, air, and water have resulted in heavy metal pollution in the environment that has serious toxicological effects on humans (Briffa *et al.* 2022).

Table 3. Residues of electronic 'forever chemicals' (mg/L) in randomly located wells that supply drinking water.

'Forever chemical'	Location	Residues in groundwater (mg/L)	WHO's permissible level (mg/L)
Pb	Nigeria (north)	0.016	0.01
	Nigeria (central)	0.07	
	Nigeria (south)	0.21	
	China (NE)	0.48	
	India (N)	2.06	
	Pakistan (Kasur)	0.14	
	Pakistan (Punjab)	0.49	
Cu	China (NE)	1.75	0.01
	India (N)	0.20	
	Pakistan (Punjab)	0.41	
Zn	China (NE)	8.11	3.0
	India (N)	0.76	
	Pakistan (Kasur)	0.14	
	Pakistan (Punjab)	1.07	
Cd	Nigeria (north)	0.22	0.05
	Nigeria (central)	0.16	
	Nigeria (south)	0.314	
	China (NE)	0.42	
	India (N)	0.45	
Hg	Nigeria (north)	0.17	0.001
	Nigeria (central)	0.08	
	Nigeria (south)	0.27	
Ni	China (NE)	6.87	0.1
	India (N)	2.92	
	Pakistan (Kasur)	0.11	
	Pakistan (Punjab)	0.10	
As	China (NE)	3.12	0.01
	Pakistan (Punjab)	0.039	
Cr	China (NE)	2.98	0.003
	India (N)	0.66	
	Pakistan (Kasur)	1.32	
Se			0.01
PFAS	USA	1-2000 ng/L	Depends on type

Meta-analysis by Wen *et al.* (2022) of rising heavy metals in surface waters (rivers and lakes) shows an alarming increase in Cadmium (Cd), lead (Pb), Nickel (Ni), Aluminium (Al), Chromium (Cr) and Arsenic (As) (Fig. 7). Of course, I'm not saying that all these substances come out of Solar Technologies, but they are ALL PRESENT as components of solar technologies used at USSP facilities, and they are all present within industries manufacturing electrical equipment. Only a portion of this electrical equipment is used within solar technologies.

Figure 7. A review of heavy metals in rivers and lakes shows a dramatic rise of Pb, Cd, Ni, and other leachates produced by the electronics industry from the mid-1990s. These heavy metals are deposited on soils, dispersed as airborne particulates, finish as end-of-life waste in landfills, and some as leachates under solar panels (Zhou *et al.* 2020), until many are then washed into surface waters.



Meta-analysis of changes in PFAS in wastewater globally has been undertaken (Cookson *et al.* 2022). Unsurprisingly this shows that influent water contamination (PFAS in drinking water) is closely correlated with effluent water (PFAS in wastewater; Fig. 8)

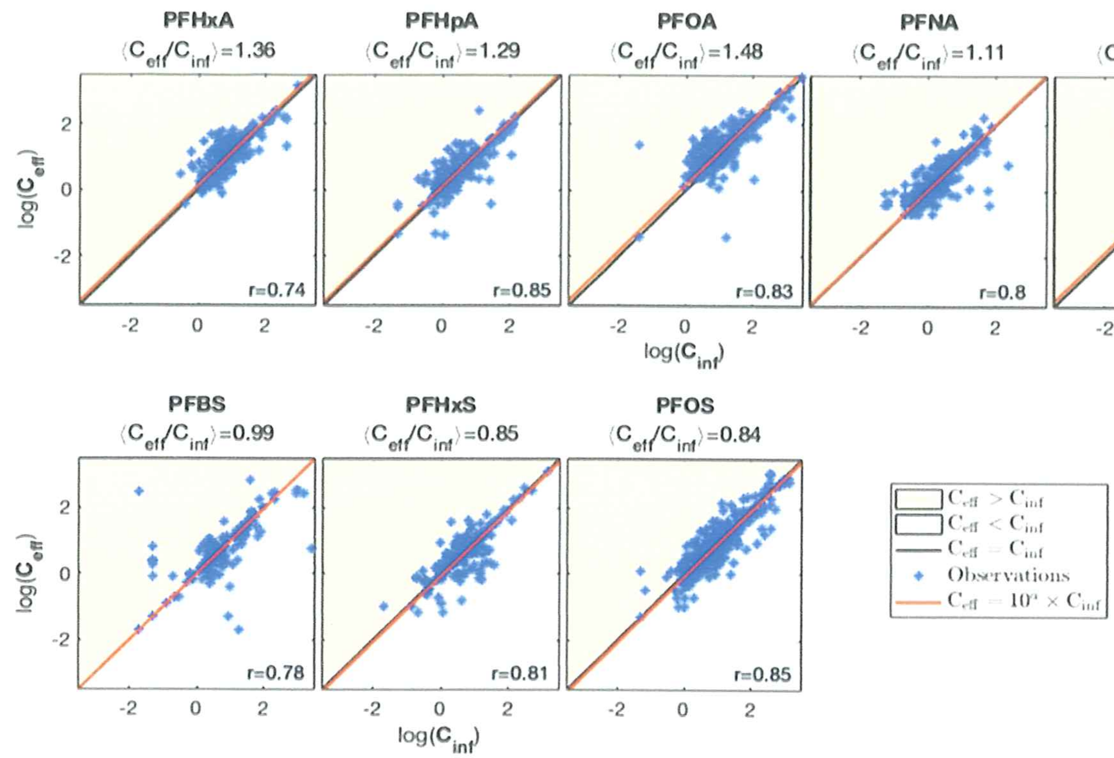


Figure 8. The correlation between PFAS in effluent wastewater and PFAS in influent water.

When we look at PFAS in wastewater over the past 15 years within nations like China that manufacture commodities containing these substances and use them in solar technologies, then the population is progressively getting more-and-more contaminated by PFAS (Cookson *et al.* 2022).

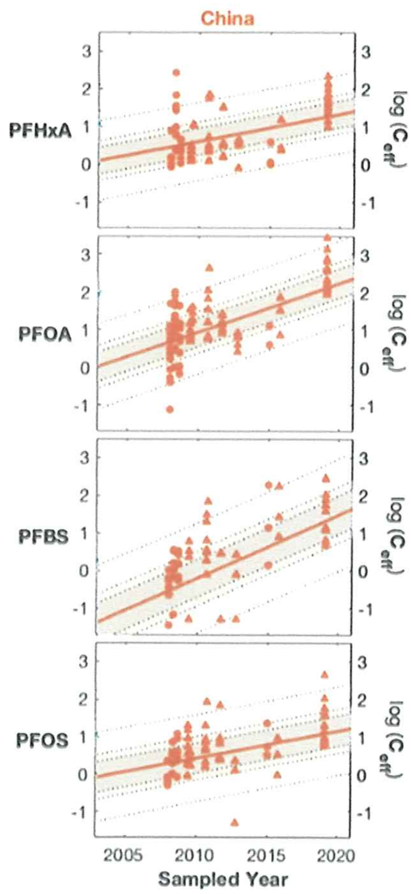


Figure 9. The increase in different types of PFAS in wastewater in China.

Even if concentrations of PFAS in the NZ environment are currently low (see MoE 2018), they may increase over time and add to the burden of hazardous substances confronting infants and young persons (see Health below). Undoubtedly solar farms will be another source of those contaminants.

Summary

All solar technologies leak metal halides and PFAS onto soils that then accumulate in the food web. The leakage of these substances each day may be small, but over a 35-year period the amounts of contaminants found in soils will be substantial. Many authors have commented on the likely high costs of soil remediation when solar panels are removed and allude to the risks when soils are once again farmed. Furthermore, the amounts of these hazardous substances accumulating in aquatic systems and entering Lake Ellesmere through run-off is also likely to be significant over a 35-year period. These are 'forever chemicals' that are not going to magically disappear from Lake Ellesmere; and they are not going to magically disappear from drains and creeks that flow around the USSP-facility.

At almost all landfills e-waste creates residues in water, soil, and air that exceed international guidelines. These contaminants then enter the food web and impact all flora and fauna including man. New Zealand currently has **no national policy on e-waste for casual disposal of just a few solar panels.** However, for industries whose annual turnover exceeds $10 million then there must be a declared plan under the 'Sustainability Act' for recycling of e-waste. In the RMA consent provided by the applicant, there is no indication of where or how he will dispose of damaged materials during the project; and, how the mass of e-waste will be disposed of both at the 20-year mark (as the efficacy of panels declines) and at the end-of-project timeline.

Impacts on soil micro-organisms.

Most soil micro-organisms are sensitive to heavy metals and PFAS that are added to soils (e.g., Jarosławiecka *et al.* 2022). Unsurprisingly, when the activity of soil microbes is reduced, this reduces plant growth and the amounts of carbon and nitrogen sequestered beneath ground.

Wang *et al.* conducted a battery of *in vivo* toxicity studies for leachates from three Pb-based solar panels (CH3NH3PbI3, NHCHNH3PbBr3, and CH3NH3PbBr3) among *Vibrio fischeri, Pseudomonas putida*, and other natural microbes extracted from soils. CH3NH3PbBr3 was identified as the most toxic Pb-based PSCs to soil microbes with an effective concentration of 50% (EC_{50}) value of 8.07 (6.65–9.85) mg/L, followed by CH3NH3PbI3 with an EC_{50} value of 9.27 (7.96–10.76) mg/L, and NHCHNH3PbBr3 with an EC50 value of 12.81 (10.64–15.34) mg/L . *V. fischeri* showed the highest sensitivity with EC_{50} values (30 min exposure) ranging from 1.45 to 2.91 mg/L. Other studies have been completed which summarize the effects of other types of heavy metal leachates on soil micro-organisms (e.g., Jarosławiecka *et al.* 2022).

In their review of impacts of photovoltaic panels on soils Moscatelli *et al.* (2022) states: "The main results from trials in Italy showed that seven years of soil coverage modified soil fertility with the significant reduction of water holding capacity and soil temperature, while electrical conductivity (EC) and pH increased. Additionally, under the panels soil organic matter was dramatically reduced (−61% and − 50% for total organic carbon and total nitrogen respectively compared to the gaps between panels), inducing a parallel decrease of microbial activity assessed either as respiration or enzymatic activities. As for the effect of land use change, the installation of the power plant induced significant changes in soils' physical, chemical and biochemical properties creating a striped pattern that may require some time to recover the necessary homogeneity of soil properties after power plant decommissioning".
This of course raises the point as to whether solar panels should have been put on productive land in the first place. In their review of a GIS land-based system for assigning lands suitable for USSP facilities Calvert *et al* states "the benefits of this new land-based economy include diversification from traditional farming practices which is welcomed for owners of low-quality land conventionally used for grazing, but the productivity of fertile lands must be preserved for bio-organic farming". The d-base modelling of cost-benefits undertaken by Calvert has not been done for the New Zealand landscape. Here in New Zealand, it is yet another case of "lets dive headlong into failure and hope to hell it doesn't happen".

There can be little doubt that heavy metal leachates and the presence of photovoltaic panels at Brookside will severely impact soils, suggesting that these impacts trigger a HSNO classification of 9.2B.

Uptake by plants

All 'forever chemicals' (i.e., metal halides and PFAS) are taken in by the roots of plants and bioaccumulate in stems, leaves and the seed and/or fruits of the plant. We will give examples of bioaccumulation of PFAS and metal halides in plants, and then look more generally at concentrations in the fruit, berries, cereals, vegetables, and herbs that we eat.

i) Bioaccumulation

In his 2021 publication Lesmeister *et al.* reviewed the uptake of PFAS by plants and describes how rates of bioaccumulation differ depending on numbers of perfluorinated carbons in the compound (Table d). What is apparent from this analysis is that for the less complex PFAS (i.e., the compounds with 4 perfluorinated carbons that are more water soluble), they have concentrations of PFAS in the shoots of plants that are 5.5-12.5x greater than the concentrations of these substances in soils. This happens because the plant bioaccumulates the PFAS. Vegetables and fruits with high concentrations of PFAS are then harvested and eaten by man, or consumed by animals, that in turn bioaccumulate them in their livers and kidneys.

BAFs for PFCAs and PFSAs with the same perfluoroalkyl chain length in wheat (pot experiments, differently spiked soil levels). Source of values: Zhao et al. (2014).

Number of perfluorinated carbons	PFAA soil concentration/(μg/kg)	PFAA shoot concentration/(μg/kg)	
		PFPeA	PFBS
4	200	2481 ± 449	643 ± 45.6
	500	3624 ± 595	1394 ± 32.6
	1000	5347 ± 127	2065 ± 253
Number of perfluorinated carbons	PFAA soil concentration/(μg/kg)	PFAA shoot concentration/(μg/kg)	
		PFHpA	PFHxS
6	200	165 ± 9.27	147 ± 13.6
	500	285 ± 6.13	255 ± 8.72
	1000	493 ± 75.2	493 ± 45.8

[a] Calculated.

In the 2nd example we cite the example of uptake of lead (Pb^{2+}) into plants from soils under PV solar panels. In China where mint was grown (Li *et al.* 2020) with "normal" lead concentrations in soils (i.e., 36.3 mg/kg) only a quarter of that lead occurred in leaves (i.e., 8mg/kg). However, where lead concentrations in soils were enhanced by the leachates from solar panels to 250 mg/kg (i.e., leachates from damaged panels) then the concentrations in leaves increased to as much as 426.8 mg/kg in leaves (i.e., 1.7x soil concentrations). This concentration in the leaves of herbs is 40x the permitted concentration of 10mg/kg by Chinese markets. If we look at the concentrations of lead in the roots of plants, then they are 15x the concentration in soils. Therefore, the problem of bioaccumulation becomes very problematical with root crops like potatoes, carrots, parsnips, kumara, and yams for human consumption; or, turnips, swedes, mangles, and fodder beet grown for livestock.

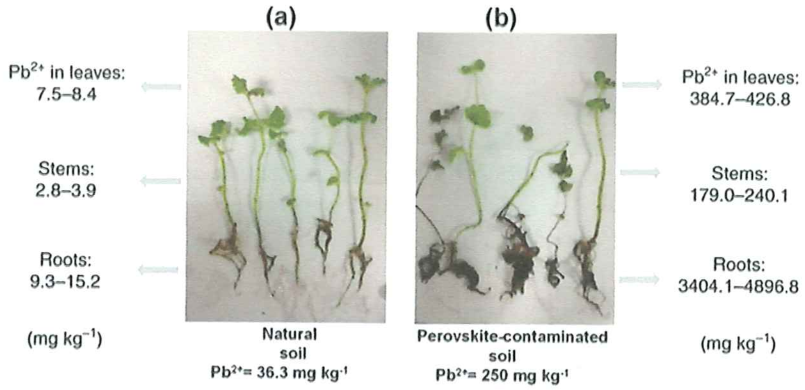


Figure 10. **`Bioaccumulation of Pb^{2+} in the roots, stems and leaves of mint in leachates from solar panels.**

The 3rd example is that of berry crops. Blackberries grown in contaminated soils bioaccumulated 29x the permitted lead (pb^{2+}) concentration, so 100g of this fruit per week over a month constitutes enough Pb^{2+} to cause nephrotoxicity and neurological symptoms of lead poisoning.

In the 4th example we look at PFAS in water and the uptake of these PFAS into a) strawberries and b) lettuce (Blaine *et al.* 2014). The PFAS eaten with these fruits and vegetables (Fig. 11) subsequently bioaccumulate in our bodies by binding to proteins in blood, and organs that are recipients of blood (placentas, heart, liver, kidneys), and so can occur at high concentrations in a baby at birth and then in infants that are breast fed.

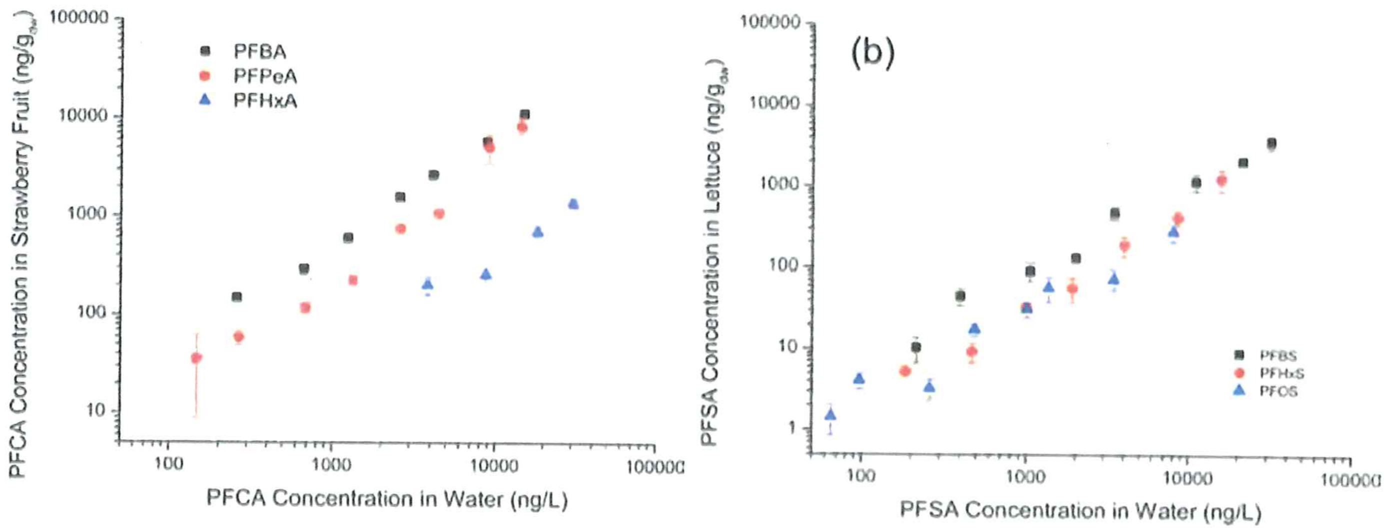


Figure 11. PFAS in a) strawberries and b) lettuce that are irrigated with water containing PFAS leachates.

The 5th example is uptake of heavy metals leached from thin-film solar panels onto brassicas (Su *et al.* 2019). Oxisol soils (from the tropics) with high acidity (pH=3.9) and naturally high aluminium would not grow brassicas once heavy metals from solar panels were added into the mix. However, mollisol soils (high in organic matter, pH≈5.8) and commercial soils from China with high pH grew brassicas successfully. Commercial soils (pH≈7) spiked with 7.5 and 10% of the potential leachates from these solar panels contained toxic levels of heavy metals after plants had grown for 60 days or more in soils. After 60 days at these concentrations plant growth was impeded by Al and so aluminium concentrations asymptote at 350 mg/kg. Even low concentrates of leachates (2.5 & 5%) raised aluminium in soils with high pH.

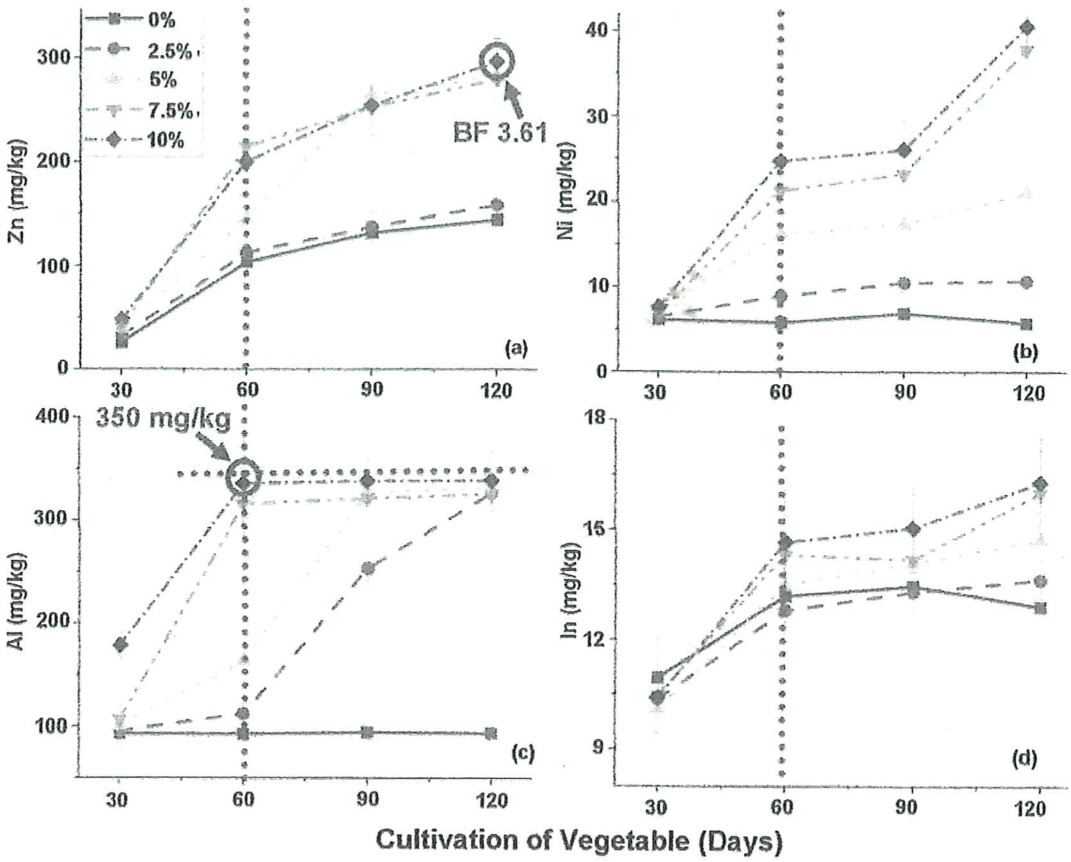


Figure 12. Uptake of zinc, Nickel, aluminium, and indium by plants grown in soils containing 0, 2.5%, 5%, and 10% of the heavy metals from solar panels.

Research on aluminium in soils shows at high pH the contaminants remain trapped in aluminosilicates and therefore uptake by plants is limited (Fig 13). However, once pH drops below 5.8 then increasing amounts of aluminium are released that add to the leachates from solar panels. More importantly as this aluminium becomes bioactive it causes toxic levels of aluminium in plants growing in acid soils. This aluminium reduces enzyme reactions such as those elicited by mycorrhizae to produce nitrogen around roots.

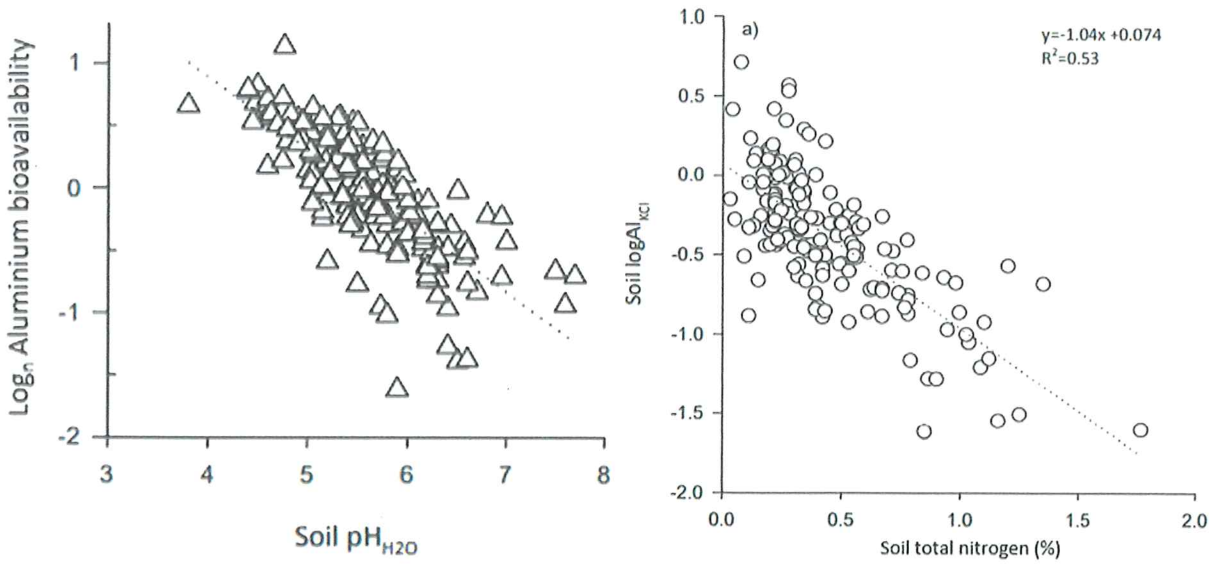


Figure 13. As soil pH is lowered a) this frees up more aluminium, b) that reduces mycorrhizae and soil nitrogen.

The effects of low pH in the presence of aluminium leachates thus lowers soil nitrates (Fig 13b) and the amounts of grass produced. Low pH with a surfeit of aluminium also increases the amounts of aluminium in grass cut for hay (Fig. 14). A similar thing also happens with zinc and copper under solar panels. These effects produce toxic levels of aluminium, zinc and copper in grass or hay. When that hay is fed to livestock, they ingest inordinately large amounts of aluminium that affects animal health and animal fertility.

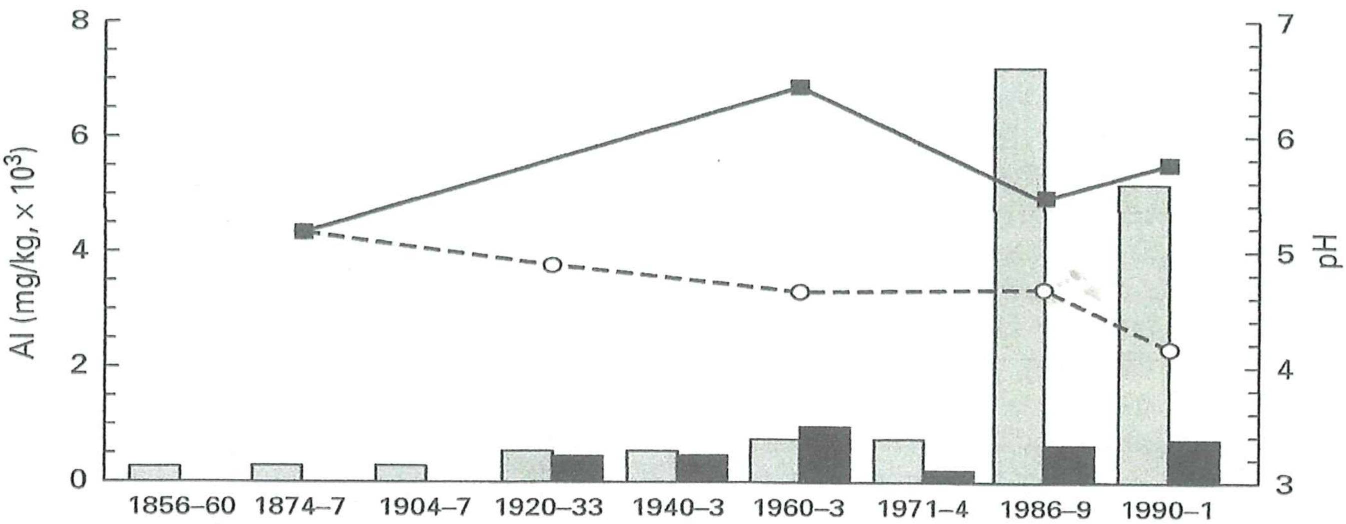


Figure 14. Aluminium in the hay of soils that have been limed and now have a pH in the range 6-7 (dashed line), and aluminium in hay that has been harvested from acid soils with a low pH (solid line).

Summary

In summary, through processes of bioaccumulation of metal halides and PFAS, any produce from solar farms that is grown on contaminated soils and then exported (e.g., herbs, onions, strawberries, etc.), will inevitably result in primary produce containing heavy metals and PFAS bioaccumulated from those soils. Irrigation of that produce with water contaminated by solar technologies is also problematical. For a nation that up till now has prided itself on high quality produce that is "100% pure", this potentially is a huge step backwards. Stock that are grazed under solar panels will bioaccumulate heavy metals in livers and kidneys making consumption of their vital organs a significant risk.

From the perspective of Brookside residents, they will pick up metal halides and PFAS on their properties within dust, in the faeces of birds and small vertebrates that feed at the USSP site, and potentially in surface water washed off site or in groundwater that acts as a reservoir for leachates that have permeated through wet soils over winter.

Contaminants from electronics (including solar technologies) in food.

The guidelines for heavy metals in food published by the New Zealand Food Safety Authority (NZFSA) are listed in Table 5 below. Concentrations of these substances that exceed guidelines inevitably impact health through sub-chronic exposures over a long period of time.

Table 5. Maximum levels of metal contaminants in food.

Metal contaminant	Food type	Maximum level (mg/kg)
Arsenic (total)	Salt	0.5
	Cereal grains	1
	Crustacea	2
	Fish	2
	Molluscs	1
	Seaweed	1
Cadmium	Chocolate & Cocoa	0.5
	Kidney of cattle sheep and pig	2.5
	Leafy vegetables	0.1
	Liver of cattle sheep and pig	1.25
	Meat of cattle sheep and pig	0.05
	Molluscs	2
	Peanuts	0.5
	Rice	0.1
	Root and Tuber vegetables	0.1
	Wheat	0.1
Lead	Brassicas	0.3
	Cereals, pulses and legumes	0.2
	Edible offal of cattle, sheep, pig	0.5
	Fish	0.5
	Fruit	0.1
	Infant formula products	0.02
	Meat of cattle, sheep, pig, poultry	0.1
	Molluscs	2
	Vegetables	0.1

Meat

A quick appraisal of average contaminants in meat in various nations are summarized in Table 6. We have intentionally targeted 5 nations with low, moderate, and high levels of contamination by heavy metals. The implications for the health of peoples in nations with contaminated soils are significant.

Table 6. **Leachates in meat products (mg/kg)**

Chemical	location	Beef	Pork	Goat/ mutton	Chicken	Cows Milk	Fish	Molluscs	Crustaceans	Liver beef	References
Pb	Italy (S)	0.019	0.024			0.002	0.2	.09	.01		Bella *et al.* 2020
	Thailand	0.04	0.032		0.032			0.167	0.10		Jankeaw *et al.* 2015
	Pakistan	2.7	3.25	2.15	2.3					11.8	El-Salam *et al.* 2013
	China (Be	0.21	0.30	0.13	0.29						
	B. (Dhaka					0.03					
As	Italy (S)	0.012	0.015			<LOD	4.95	22.7	9.5		Bella *et al.* 2020
	China (Be	0.077	0.043	0.008	0.045					1.5	
Cd	Italy (S)	<LOD	<LOD		<LOD	<LOD	0.0015	0.003	0.003		Bella *et al.* 2020
	Thailand	.024	0.008		<LOD			0.004	0.009		Jankeaw *et al.* 2015
	Pakistan	0.475	0.35	0.375	1.15					0.83	El-Salam *et al.* 2013
	China (Be	0.015	0.003	0.031	0.031					0.98	
	B. (Dhaka					0.06					
Cr	Italy (S)	<LOD	<LOD			<LOD	0.019	0.02	0.02		Bella *et al.* 2020
	Thailand	0.02	0.019		0.015			0.018	0.029		Jankeaw *et al.* 2015
	Pakistan	0.3	0.49	<LOD	0.075					15.76	El-Salam *et al.* 2013
	China (Be	0.504	0.483	0.654	0.650					0.19	
	B. (Dhaka					0.53					
Hg	Italy (S)	<LOD	<LOD			<LOD	1.14	.21	.59		Bella *et al.* 2020
	China (Be	0.010	0.015	0.005	0.017					0.049	
Ni	Italy (S)	<LOD	<LOD			<LOD	0.004	.05	.01		Bella *et al.* 2020
	Pakistan	0.05	0.225	0.063	0.25					0.22	El-Salam *et al.* 2013
	China (Be	0.061	0.015	0.061	0.069						
Zn	Italy (S)	48.9	44.9			<LOD	3.96	13.94	18.05		Bella *et al.* 2020
	Pakistan	29.65	26.41	26.41	7.4					23.1	El-Salam *et al.* 2013
Cu	Pakistan	7.31	3.01	4.09	2.51					12.5	Bella *et al.* 2020
	China (Be	0.673	0.633	0.956	0.535					50.0	
	B. (Dhaka					0.12					
PFAS	Germany		1.4 ng/g				Wild boar livers= 117 ng/g (liver) 1.4 ng/g (muscle)				Knutsen *et al.* 2018
PFAS	Germany						Wild boar livers= 16.9-24.2 ng/g(liver)				Felder *et al.* 2020
PFAS	Bavaria						Wild Boar Livers=117-408 ng/g				Kowalczyk *et al.* 201
Heavy metals	Germany						Wild boar livers Pb=0.195 Cd= 0.483 As=0.054 Zn=62.77				Kasprzyk *et al.* 2020

- In Italy mercury and arsenic exceed guidelines for seafood, with all other heavy metals at low-moderate levels in oceans. The contamination of seafood increases infant cancer risks;
- In Thailand heavy metals in seafoods are low-moderate, residues in meat are moderate. These levels of food contaminants are on average slightly higher than Italy; so seafoods and meats present a health risk, and infant cancer risks are moderate;
- In China the residues of heavy metals in meat are high, and residues in livers of animals are high. The infant cancer risks are high. Infant health is now very poor (*see* below).
- Pakistan meats and meat by-products are all very high in heavy metals and exceed international guidelines for contaminants. The health risks in Pakistan for infants and children are very high;
- The livers of wild boar (that eat carrion and plant roots) are a good indicator of heavy metals and PFAS in the environment. Just as wild pigs proved to be a good indicator species for both Tb in wildlife and brodifacoum in wildlife here in NZ, wild pigs are also adept at bioaccumulating contaminants. The wild pig vacuums up birds, small mammals, invertebrates etc that have died from excess metal halides. The heavy metals in carcasses eaten by wild boar then bioaccumulate in livers until they contain excess quantities of PFAS, Pb,

Cd, As, and Zn. Results for residues in wild boar in Germany vary in different studies depending on whether they were taken from "contaminated" sites or areas with low levels of environmental contamination.

Cereals from plants grown in soils with high metal contaminants all contain high residual amounts of heavy metals and PFAS (Table 7).

Table 7. Leachates in cereals (mg/kg) grown in soils containing chemicals associated with e-waste (Mahmud.

Metal Halides	Location	Rice	Wheat	Wild Rosehip berries	Milk	Green veges
Pb	China (Henan)	0.53	0.99			
	China (Gansu)		1.29			
	China (Beijing)		0.17			
	China (Anhul)	0.06				
	China (Hebei)	0.03	0.15			
	China (Balyin)	0.11	9.96			
	Bangladesh	0.10				
	Croatia			3.34		
As	China (Henan)	0.10	0.11			
	China (Anhul	0.18				
	Bangladesh	0.39				
Cd	China (Henan)	0.016	0.02			
	China (Gansu)		0.61			
	China (Beijing)		0.04			
	China (Anhul)	0.21				
	China (Hebei)		0.15			
	China (Balyin)		0.75			
Cr	China (Henan)	0.21	0.18			
	China (Beijing)		4.62			
	China (Hebei)		0.69			
Al	Croatia			8,242		
Cu	China (Gansu)	6.84				
	China (Beijing)		6.09			
	China (Anhul)	8.7				
	China (Hebei)		1.79			
	China (Balyin)		7.61			
Ni	Bangladesh	8.4				
	Croatia			11.3		
PFAS	New Mexico				5,000ppt[i]	13-566[ii]

i) In New Mexico, the US Air Force contaminated groundwater at their air base with PFAS. All 3,665 cows on an adjoining farm that used that same groundwater for stock had to be euthanized, and all milk containing >5,000ppt PFAS was disposed of. The groundwater exceeded PFAS guidelines for years after contamination.

ii) The FDA has found PFAS in brassicas and other green crops at concentrations of 13-566 ppt (i.e., well above FDA safety limits).

iii) Heavy metals in cereal crops in China at contaminated sites exceed international food standards because soils are very contaminated with industrial pollutants that include heavy metals and PFAS. Waters used to irrigate crops contain high levels of heavy metal, and so pollutants go around and around in a pollution cycle (i.e., water to crops, crops to animals, cereal and meat with pollutants to man, man to surface and groundwater, from contaminated waters then back onto crops, etc.).

iv) Many of the heavy metal contaminants in water, crops, and meats out of Asia now exceed the upper limits of NZFSA guidelines for healthy nutrition.

v) Wild rosehip berries (Zeiner *et al.* 2018) at contaminated sites had bioaccumulated on average 8242 mg/kg of aluminium (Al), 11.3 mg/kg of nickel (Ni) and 3.34 mg/kg of lead (Pb); all contaminant levels well above WHO guidelines.

Contaminants from electronics in honey

Honey is now regarded as an international barometer for environmental pollutants; with some honey samples showing New Zealand is now as bad as Iran, Ethiopia, and worse than "contaminated sites" in Lithuania.

In the relatively unpolluted countryside of Lithuania, the pollutants typically associated with the electronics industry (Cd, Pb, Cr, Cu and Ni) were on average more than doubled in honey from "contaminated sites" compared to the unpolluted "control" sites (Table 8).

Table 8. Pollutants in honey (from 11 sites) throughout Lithuania (ng/g)

	Sites	Cd	Pb	Cr	Cu	Ni
Control	n=3	0.002	0.011	0.021	0.053	0.023
Contaminated	n=8	0.004	0.221	0.035	0.156	0.049
Increase	(x cont.)	2.4	19.9	1.7	3.0	2.2

Throughout Europe the problem of metal halides and PFAS in honey has escalated with the arrival of more-and-more e-waste in the environment. In some countries now the levels of e-waste in honey is close to European guidelines of 0.1 mg/kg for Pb^{2+} and 0.1 mg/kg for cadmium (Table 9)

Table 9. Heavy metals in honey samples from various nations throughout the world.

Studies	Zn	Cu	Pb	Cd	Mn	Cr
European Guidelines			1.0	0.1		
Iran(by Razzagh and et al., 2015)	2.03–6.8	-	0.08–0.12	-	-	-
Ethiopia (by Gebru and et al., 2015)	0.65–0.93	0.13–0.23	0.03–0.1	0.02–0.03	-	-
Kenea (Erene 2012)	1.01-2,1	0.07–0.24	0.01–0.05	0.01–0.05		-
Ethiopia (Shibru 2014)	-	0.085–0.133	0.152–0.201	0.07–0.222		-
Nigerea(EzehErnesti and et al., 2018)	-	-	0.175	0.088	-	6.67
Ethiopia (Wolde and et al., 2018)	1.92–4.22	ND-0.468	ND	ND-0.69	ND-0.885	1.20–4.33
Ethiopia (Ashenafi 2018)	0.062–0.33	0.027–0.0697	-	-	0.0693–0.815	-
Turky(Tuba and et al., 2015)	0.48	0.15	-	-	0.187	-
Ethiopia 2018 study (present study)	1.97–2.04	1.92-2	ND	0.025–0.031	0.83–1.01	0.25–0.45
New Zealand (Grainger *et al.* 2021)			0.01–0.0765	0.005—0.052		

Although New Zealand likes to sell itself as 'clean and green', a study on samples of honey from 6 regions of the North Island showed Pb in honey near roads at 9.5-76.5 µg/kg and cadmium at 5–51.6 µg/kg. Unsurprisingly, with cadmium added to soils in the Waikato, the levels of cadmium in honey at some locations in this region are close to European guidelines for contaminants.

For beekeepers around Brookside there will inevitably be more heavy metals and PFAS in their product following 35 years of site contamination by a solar farm. These contaminants create more heavy metals and PFAS in the nectar of flowers.

Contaminants from the electronics industry in humans

We must reiterate again that USSP facilities are comprised mainly of heavy metals and PFAS that will be constantly leached into soils, water, and air throughout a 35-year period at the Brookside site. In year 1 the effects are likely to be small, but by year 20 when panels are delaminating, then leachates are likely to have a major impact on the environment and human health. Any weather event such as gales, lightening, hail, and a freeze-thaw following heavy snowfall that damages solar panels will deposit "pulses" of heavy metals into the food web. Heavy metals are well-known environmental pollutants owing to their toxicity, longevity in the biosphere, and ability to accumulate in plants, animals and the human body *via* bioaccumulation. Leachates of e-waste into groundwater and the pollution of terrestrial and aquatic ecosystems with heavy metals and PFAs is currently a major environmental concern that has consequences for public health. The New Zealand Parliamentary Commissioner for the Environment produced a report in 2022 entitled "Knowing what's out there: Regulating the environmental fate of chemicals". This report highlighted the need to reduce environmental contamination by heavy metals; yet at the minute solar technologies on farmland potentially represent a big repository of those heavy metals and a threat to ecosystem health. This conflict of regulatory ideologies to keep New Zealand clean and green (Parliamentary Commissioner for the Environment) *versus* 'leachates' from solar technologies as is being promoted by the 'Greens', are facets of environmental health that need a resolution.

Heavy metals are characterized by their high atomic mass and toxicity to living organisms. Most heavy metals cause health consequences that at a minimum result in 'target organ toxicity' and at worst may be lethal to humans. Heavy metals can also become strongly toxic as they mix with other elements. Humans and other living organisms in a contaminated environment inevitably get exposed to 'forever chemicals' in the food chain. The implications of heavy metals with regards to children's health have been noted to be much more severe compared to that of adults.

A review of selected PFAS on the European population was carried out in 2018 (Knutsen *et al.* 2018). A further review by Parvez *et al.* in 2021 focussed on the health consequences from exposures to heavy metals and PFAS in food, water, and air. Results from these meta-analysis that encompass thousands of adults, children, infants, as well as the natal monitoring of contaminants in the placentas of babies demonstrate the following:

- PFAS in the placentas of pregnant women at contaminated sites (27.1, *n*=653) are higher than in reference sites (7.8).
- PFAS in the blood serum of infants at contaminated sites (4.77, n=232) were higher than at reference sites (1.4).
- PFAS in the lipid of infants (4.4, n=150) at contaminated sites were higher than at reference sites (2.0)
- PFAS in the lipid of adults (3.6, n=383) at contaminated sites were higher than at reference sites (1.6)
- PFAS in the urine of infants (3.1, n=118) at contaminated sites were higher than at reference sites (1.7);
- PFAS in the urine of adults (2.0, n=531) at contaminated sites were higher than at reference sites (0.5)
- Pb^{2+} in the placentas of pregnant women at contaminated sites (30.4 mg/kg, *n*=226) are higher than at reference sites (4.7).
- Pb^{2+} in babies at parturition within contaminated sites (9.96, *n*=369) are higher than at reference sites (6.3).
- Pb^{2+} in pre-school infants at contaminated sites (7.4, *n*=6177) are higher than at reference sites (4.7).
- Pb^{2+} in primary school children at contaminated sites (5.9, *n*=400) are higher than at reference sites (3.6).
- Pb^{2+} in adults at contaminated sites (6.8, *n*=234) are higher than at reference sites (3.16).
- Pb^{2+} in adults processing e-waste at contaminated sites (9.3, *n*=420) are higher than at reference sites (4.4).
- WHO guidelines for cadmium (Cd) in blood are 5 µg/100ml (i.e.,5 µg/dL). From day 1 a baby in China has high cadmium in the blood.
- Cd in the placentas of pregnant women at contaminated sites (6.1, *n*=170) are higher than at reference sites (3.4).
- Cd in pre-school infants at contaminated sites (1.1, *n*=1474) are higher than at reference sites (0.63).
- Cd in primary school children at contaminated sites (0.65, *n*=140) are higher than at reference sites (0.4).
- Cd in adults at contaminated sites (2.6, *n*=158) are higher than at reference sites (2.0).
- Cd in the urine of pre-school infants at contaminated sites (1.9, *n*=496) are higher than at reference sites (1.4).
- Cd in the urine of adults at contaminated sites (1.9, *n*=356) are higher than at reference sites (1.0).
- The profile of cadmium is a little different to that for PFAS and lead, because cadmium binds tightly to tissue with a high half-life in tissue of >10 years (viz. half-lives are age-dependent), so it tends to progressively bioaccumulate as a person gets older. None-the-less a baby is born with moderate levels of cadmium.

- Children born to mothers with high concentrations of metal halides and PFAS in the placenta had poor AGPAR scores at birth, had lower birth weights, were shorter, had smaller chest circumference, smaller head circumference and lower levels of cognition.

Heavy metals and PFAS in the blood adhere to body proteins that they come in contact with, which includes those areas of the body that filter blood (the kidneys, liver, and placenta) where heavy metals and PFAS become aggregated (Fig. . In sites contaminated with e-waste, the foetus in the womb is fed by a placenta that is rich in blood containing inordinately high levels of PFAS or heavy metals; consequently, natal babies have high levels of lead, cadmium, and PFAS at birth. Babies are then fed breast milk that contains heavy metals (Pb^{2+}, Cd, etc) and PFAS (Doria 2004, Zheng *et al.* 2021, Khanjani *et al.* 2018); so, have high blood lead and/or PFAS levels as they develop during infancy. Substituting the feeding of infants with cow's milk is also thwart with problems because at contaminated sites there are high residues of Cd, Cr, Pb, Mn, and Cu in that product as well (Muhib *et al.* 2016). School age children have moderate lead and PFAS levels but because of their greater body mass and slightly lower exposures, the risks are slightly lowered. When people become adults then lead and PFAS levels in China settle at a level about or slightly above the MAL for blood. This analysis shows heavy metals and PFAS are very harmful to a child's health with consequences that include mental retardation, neurocognitive disorders, behavioural disorders, respiratory problems, cancer, and cardiovascular disease.

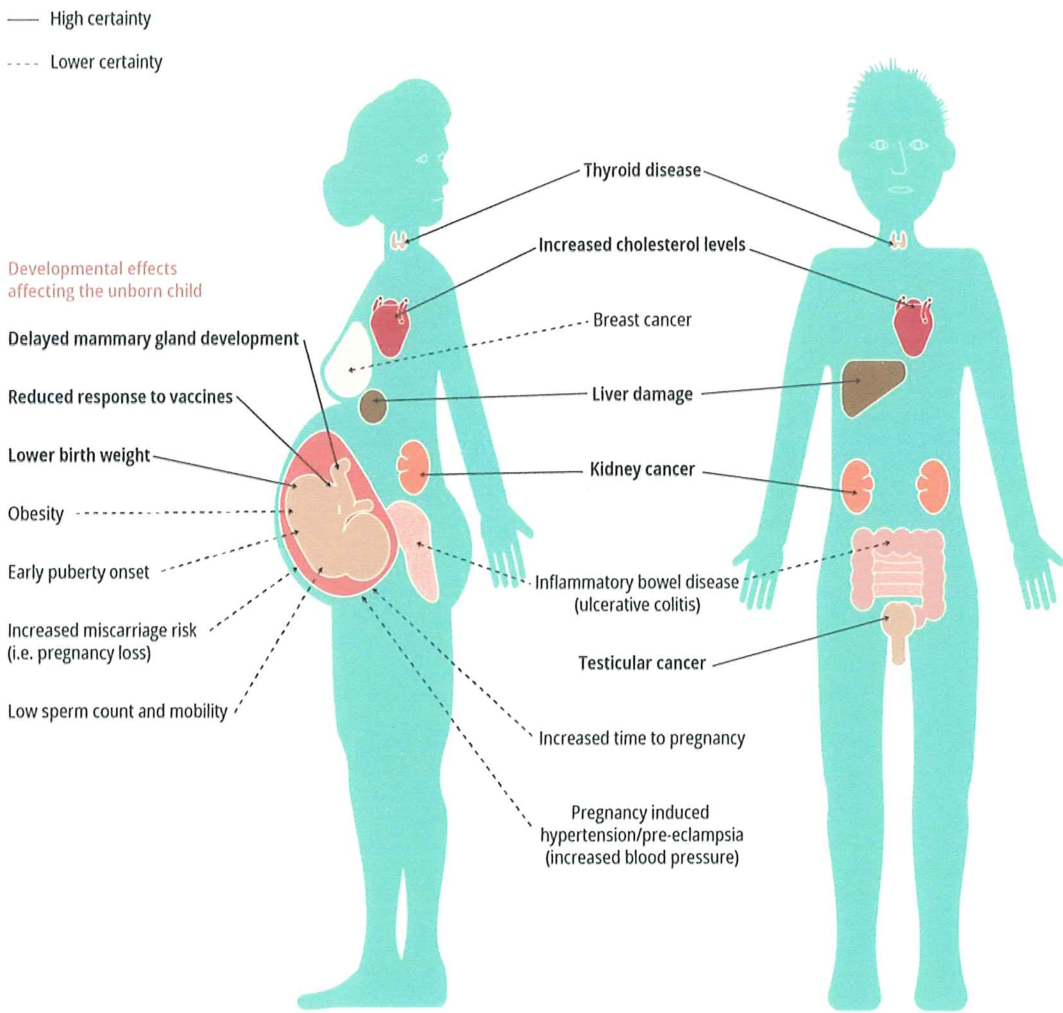


Figure 14. Sites of heavy metal and PFAS bioaccumulation in the body are in the liver, kidneys, and heart where blood if filtered and contaminants adhere to proteins. The ramifications of those things on the health of baby are severe; the ramifications on adult health are also shown. What is not included are the neurological effects from aluminium, lead, lithium, and manganese on mental health and motor neurons (see below).

The model of heavy metals and PFAS impacting the young of a species from this analysis is replicated for other species throughout the world. Birds have thinner eggshells (some breakage during incubation), contaminants are taken into the chick before it hatches, fewer chicks survive to be fledged; mammals are born with impairments to health and lowered survivorship at birth, and the fertility and/or survivorship of fish is affected by metal halides / PFAS compounds. Despite this millions of tonnes of these materials are now festooned around the globe with proponents of the technology singing a chorus of "its clean and green".

The health effects of just some of the materials used at USSP facilities are summarized in table 10.

Table 10. The health effects of the more common heavy metals & PFAS used to make solar technologies.

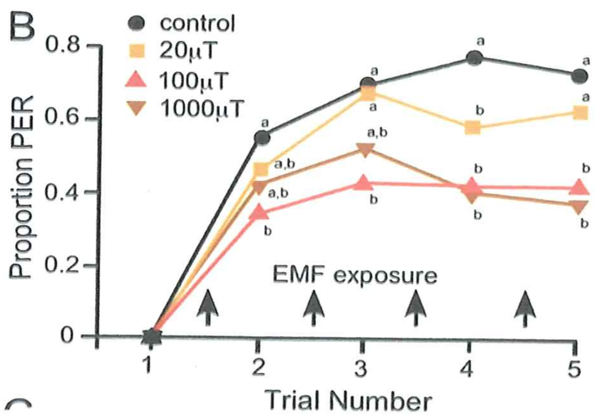
Metal	Health effects (human, animals, birds, fish) in repeated sub-chronic doses.
Aluminium (Al)	Neurological effects (e.g., dementia, Alzheimer's), anaemia, osteoporosis, lowered fertility (reduced sperm counts, it bioaccumulates in placenta & impacts unborn babies), reduces the efficacy of vaccines to children, and has high aquatic toxicity in acid waters.
Lead (Pb^{2+})	Carcinogen. Has neurological effects (lowered IQ, psychosis, dyslexia, etc), kidney failure, muscle fatigue, and has high aquatic toxicity. Woks synergistically with Cd to cause hepatotoxicity.
Cadmium	Anaemia, iron deficiency, kidney failure, liver failure, bioaccumulates and binds to tissue more than the other heavy metals (half-life in kidney=6-38 years, half-life in liver = 5-19 years) because mechanisms for elimination are poor. Has high aquatic toxicity.
Nickel	Carcinogen, neurological effects (lowered IQ, psychosis, dyslexia, etc), kidney failure, muscle fatigue, high aquatic toxicity.
Copper selenide	Highly toxic if inhaled or ingested, skin irritant, eye irritant, has very high aquatic toxicity and is persistent in waters
Copper Iodide	Toxic by ingestion, skin irritant, eye irritant, pulmonary irritant that causes respiratory disorders, very toxic to aquatic organisms (both acute and chronic)
Chromium	Carcinogen, mutagen (alters DNA), oxidizing agent that causes oxidative stress, reduces fruit & vegetable quality, aquatic toxicity high.
Selenium	Hair loss, skin discolouration, bad breath, staggers in stock, laboured breathing, respiratory disorders (respiratory irritation, bronchial spasms, coughing, bronchitis), diarrhoea, lowered fertility
Silica (glass)	Inhaled crystalline silica particles cause silicosis, lung cancer, COPD and kidney disease. Exposure also causes autoimmune disorders and cardiovascular impairment.
Arsenic	Highly toxic by ingestion. Chronic exposure from water and food causes cancer and skin lesions. Causes cardiovascular disease & diabetes. Impairs cognition and increases youth mortality.
Titanium dioxide	Carcinogen, recent research indicates it is genotoxic and so may also be a mutagen. Toxic if inhaled at concentrations >0.2 mg/m^3 (e.g., in a fire at a 'solar farm')
PFAS	Decreased vaccine response in children, increased cholesterol levels, changes in liver enzymes, increased blood pressure & pre-eclampsia in pregnant women, decreased infant birth weight, increased risk of kidney & testicular cancer, lowered sperm counts, reduced fertility.

The impacts of USSP-facilities on ecosystems

Electromagnetic fields

Low frequency electromagnetic (EMF) fields impact insects, and birds especially. It comes in many different forms; cell-phone towers, radio waves, television transmissions, and existing powerlines. Many people will say Brookside is already polluted with EMF so what is the issue? The issue is that background level EMF is not constant and is currently low-to-moderate. However, the applicant plans to build a USSP facility that generates a further 160 megawatts of electricity. With that 160 megawatts of electricity the point electromagnetic field at the substation is 40-60 μT with increased power load, and around 30 μT of magnetic field will form around transmission wires. That electricity is transported down roads in transmission lines where the electric fields affect milk production by cows as well as bee activity. With a constant aura of low-level EMF from solar technologies it is inevitable this will affect insects. Immediate effects from constant EMF will include the loss of monarch butterflies that visit Brookside gardens each year, reduced honey production (Shepherd *et al.* 2018) because of reduced bee feeding activity (Fig.

15); reduced numbers of bees leaving and returning to hives (Fig. 16); bees unable to find their way back to the hive because they are disorientated by EMF (Fig. 17); and reduced numbers of worker and queen larvae maturing as viable adults which contributes to colony collapse disorder (Fig. 18); and finally honey that is more polluted with heavy metals (*see* above).



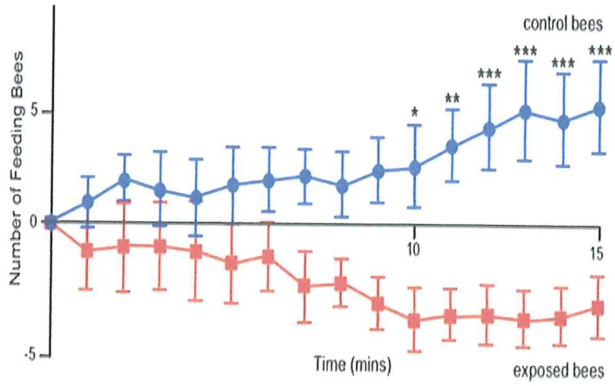
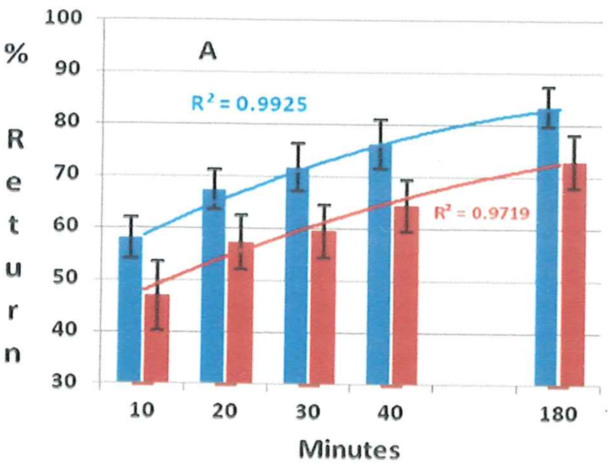


Fig 15. Bee feeding activity with exposure to magnetic fields. Fig 16. Bees entering and leaving hive low level EMF.



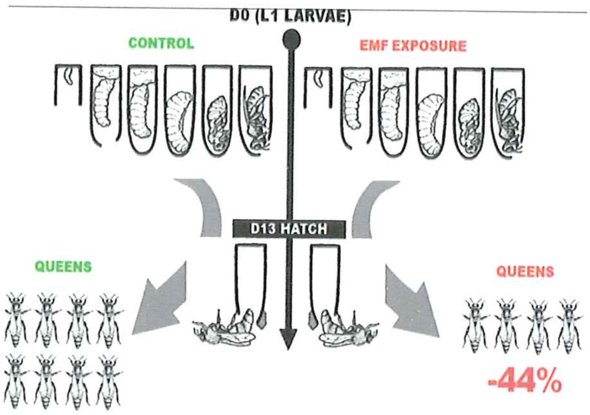


Fig 17. Bees returning over 3-hrs without and with EMF. Fig. 18. Fertility of bees without and with low level EMF

Changes in bee behaviour have been observed with very small magnetic fields as low as 0.024 μT (Walker & Bitterman 1989). To put a solar facility in the Brookside area that will at times generate 160MW of power will inevitably affect invertebrates and especially bees. (HSNO=9.4C).

Monarch butterflies

Monarch butterflies are philopatric (i.e., return to where they were born to breed). For this reason, butterflies that over-winter in Mexico fly to Canada in the summer to reproduce. They are a long-distance migratory species. The iconic Monarch butterfly is known to have magnetite in their antennae and to contain cryptochromes that aid in navigation. A 1982 study found the head and thorax areas of monarchs contained magnetic materials and a 2014 study found that monarchs' longest of all migrations from Canada to wintering grounds in Mexico is assisted by a magnetic compass. These wonderful creatures find it difficult to find their way around when EMF impacts their in-built magnetic compass; and they may find it difficult to return to gardens around Brookside once 160 Megawatts of electricity a solar farm produces an electromagnetic shield around the district.

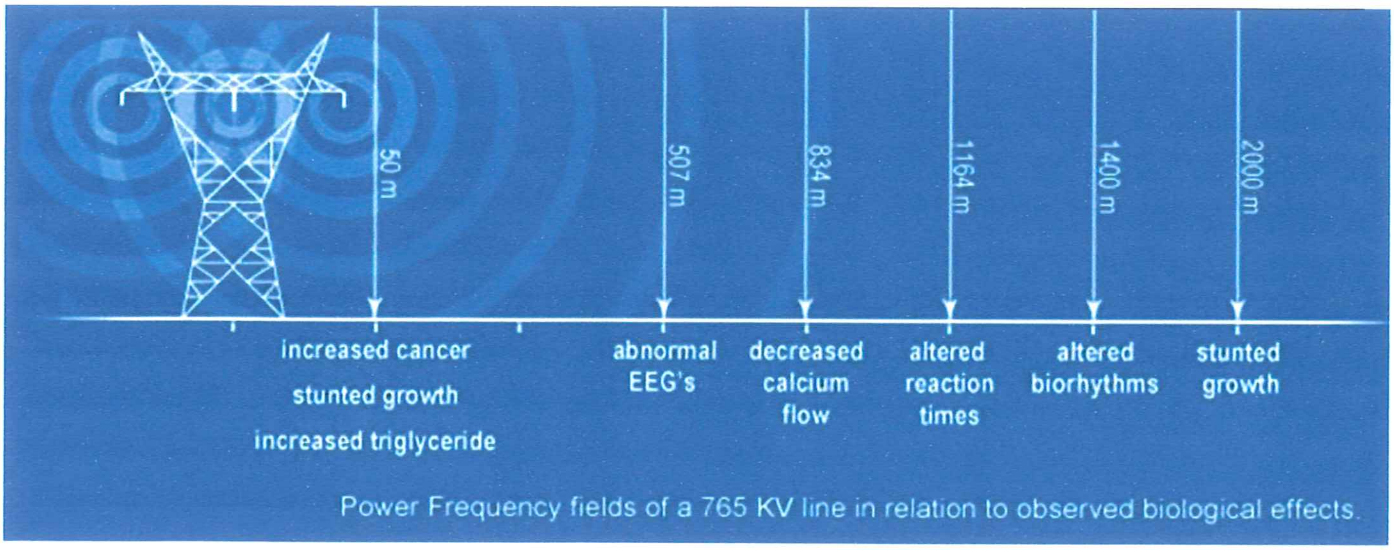
The wider implications of EMF are reviewed by Levitt *et al.* (2022), indicating that low frequency fields at low intensities affects migratory species, numerous insect species, fish, mammals, bats, molluscs, bacteria, and other micro-organisms in so many different ways, including DNA modification, changes in RNA, etc. Insect abundance in

Germany has dropped by 80% since 1990, with EMF a large contributary factor to this population decline (Hallman *et al* 2017).

The applicant wants to establish a permanent source of EMF at Brookside with all its inherent problems to ecosystem health and human health (*see* EMF dossier).

ii) Effects on health

The substation at the corners of Branch Drain Rd and Buckleys Rd represents a foci for electromagnetic fields. That site would I estimate have a magnetic field of 40-60 μT that according to past research is affecting people up to 2-km from the source of the field (*see* below). Near the substation cancer risks are high, thyroid glands are affected, thyroxine is deficient, increased triglycerides and other factors predispose heart conditions, and oxidative stress is high; 500m away brain function is altered as tested by EEG during research; over a kilometre away enzyme exchanges essential to bone growth are affected, the impacts on motor neurons are such that reaction times are slowed; 1.5k away magnetic fields are affecting biorhythms with sleep disturbance; and 2 km away calcium deposition in bones is still affected and children experience stunted growth. Of course, the same effects are experienced by cows and this reduces milk production; bees that are very sensitive are not pollinating crops and gathering honey like they would normally do, and the effects on other invertebrates are profound. These are all "reverse sensitivity effects".



The impacts of electromagnetic fields (EMF) on both human health, ecological processes at Brookside, and the local economy may include:

a) IARC (International Agency for Research on Cancer) currently classifies electromagnetic fields as class 2b substance (i.e., probable human carcinogen). This should be shown on HSNO signage.
b) Typical levels of EMF near power lines are 29.7μT, 6.5μT 15m away, 1.7μT at 30m; whereas for high voltage transmission lines they are 58μT, 20μT 15m away, 7.1μT 30m away and 2μT at 60m. Figure 18 (above) provides a schematic outline of EMF fields around transmission lines.
c) Low frequency electromagnetic fields affect the human brain even with small magnetic fields as low as 1 μT (Wang *et al.* 2019).
d) Weak electromagnetic fields affect reactive oxygen species (ROS) that lead to cancers. Rates of brain and nervous system cancers in the USA were 8.4 per 100,000 in 2015; similar to the rate of road traffic deaths

(10.9/100,000) in the same year. The sources of EMF in the community are of course multifactorial, but EMF from electricity is a major contributor.

e) Long term exposures to EMF fields showed relative risk of childhood leukaemia as 0.54 (<1 μT), 0.95 (1-2 μT), 1.06 (2-3 μT), 1.69 (>3 μT) in replicated studies (Greenland *et al.* 2000). Magnetic fields >3μT will only be encountered around transmission lines situated on rights of way.

f) Health effects such as sleep disturbances, headache, depression, depressive symptoms, tiredness, fatigue, dysesthesia (a painful, often itchy sensation), lack of concentration, changes in memory, dizziness, irritability, loss of appetite, weight loss, restlessness, anxiety, nausea, skin burning and tingling have been reported with regular low-level exposures to low levels of electromagnetic fields (i.e., <1 μT).

g) Electrical workers exposed to an average 0.16 μT of electromagnetic fields each day throughout their lives experienced several health effects after sustained EMF exposure. EMF caused inter-intracellular heating, changed chemical reactions, and disruption of molecules and atoms bonded to each other. It decreased antioxidant enzyme activity, increased oxidative stress, increased leukaemia, decreased serum osteoprotegerin, inhibited osteoblastic activity, decreased bone density, increased osteoporosis, changed the endocrinology of people, changed thyroid activity, increased thyroid nodules, and reduced thyroxine levels (Kunt *et al.* 2016). This in part explains the stunted growth in children living near overhead power lines (Figure 18).

h) High level regular exposure (i.e., 3-60 μT) to electromagnetic fields (viz. for young people living <50m from high voltage transmission lines) is often associated with cancer in later life (especially brain tumours, leukaemia, lymphoma, breast cancer), motor neuron disease, ALS syndrome (*amyotrophic lateral sclerosis),* neurological diseases (Alzheimer's, dementia, etc.), suicide, depression, hypertension, lowered heart rate, heart disease, heart palpitations, blood diseases, miscarriage, fertility problems, male genital abnormalities, and thyroid problems.

i) Currently extensive research initiated by WHO (World Health Organization) is in progress to better define the effects of EMF on health, although some of the effects listed above have already been substantiated (e.g., Barnes & Freeman 2022).

j) Irrespective of whether locals at Brookside are continuously exposed to electromagnetic fields from an additional 160 megawatts of power passing through the substation, or high levels of electromagnetic fields from power transmission both into and out of the Brookside substation, their health may be affected in various ways.

k) Bees are very sensitive to electromagnetic fields (Kirschvink et al. 1992), which reduces feeding activity, numbers of workers leaving the hive, numbers returning to the hive, and fertility (Shepherd *et al.* 2018). In a study in Poland where the effects of man-made habitat changes on wild bees were compared, most bees (60%) used overlapping habitats, vegetation alongside railways was used by 35% of bees, vegetation alongside roads used by 5% of bees, and vegetation around power lines was used by 0% of bees; so although vegetation near transmission lines was floristically diverse and prolific, the presence of EMF precluded bee activity (Twerd *et al.* 2021). Small electromagnetic fields impacted various instars of larvae during bee development in the hive, they reduced numbers of bees reaching maturity, and bee numbers in the hive (Li *et al.* 2022). Small magnetic fields as low as 1 μT not only affect bee behaviour (Migdal *et al.* 2022), but the chemical composition and DNA of bees (Koziorowska *et al.* 2020). Other research has demonstrated EMF <<1 μT affects bee colonies. In a study in 1989 most bees responded negatively to 260 nano-Teslas (i.e., 0.26 μT) and some bees were sensitive to 0.025 μT or 25 nanoTeslas) (Walker & Bitterman 1989). The EMF at the Brookside site will inevitably affect bee behaviour; it makes bees more aggressive, more likely to sting, and reduces learning ability (Shepherd *et al.* 2019). Furthermore, EMF is a factor in colony collapse disorder (Kumar 2018, Wyszkowska *et al.* 2019). In the USA during 2020, around 40% of beehives experienced colony collapse disorder, a condition that in many instances began with EMF causing agitation, disorientation, aggression, and poor cognitive abilities; then escalated to poor storage of nectar and pollen and an inability for bees to facilitate communal tasks within a colony. EMF is an abiotic environmental factor that along with habitat loss, pesticide exposure, pathogens and parasites is affecting the ability of bees to pollinate crops.

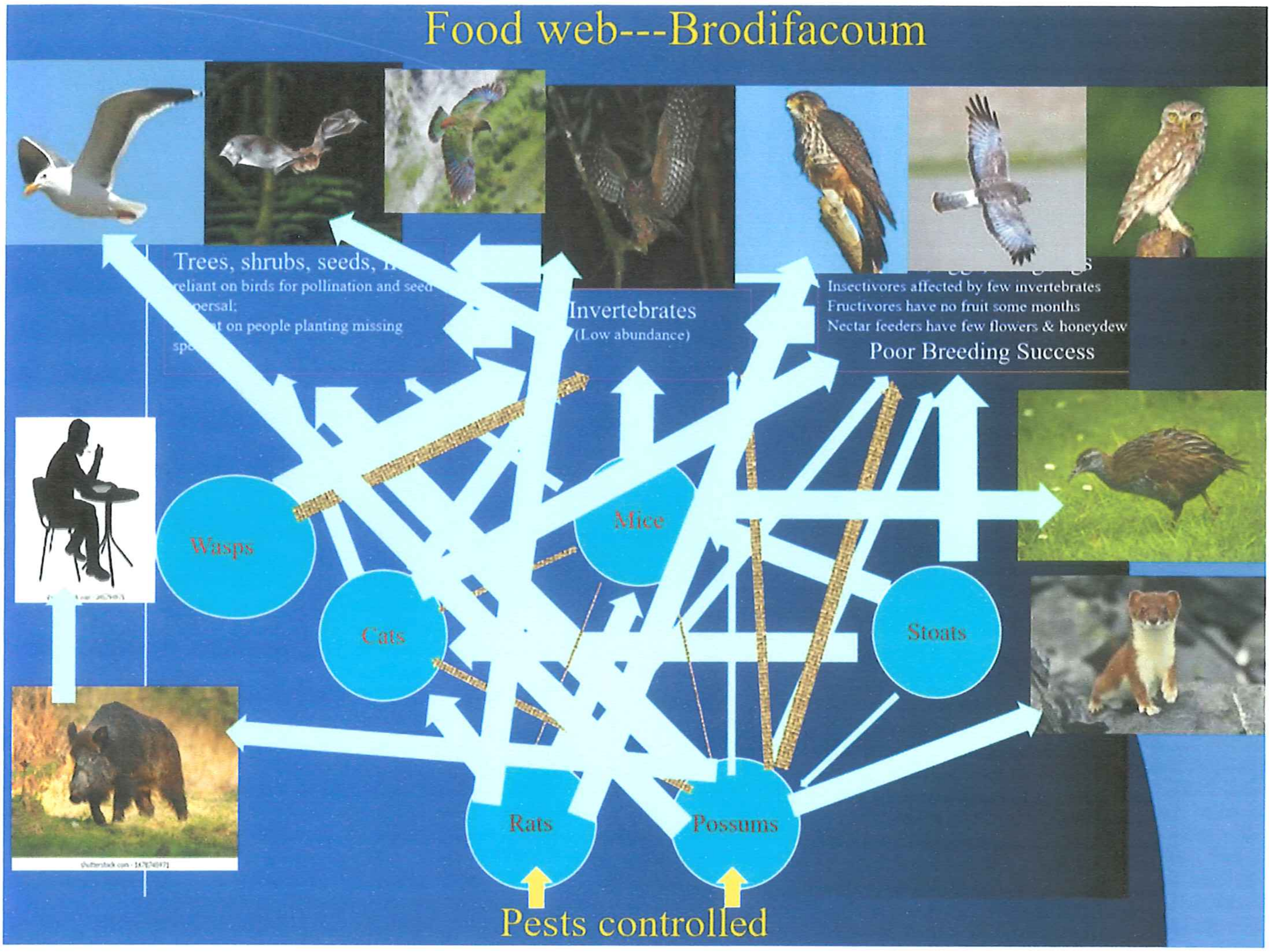
Impact of solar technology leachates on Ecosystem Health.

There is little doubt that solar panels and solar technologies will shed layers of metal halides and PFAS into the environment over the next 3-4 decades. How does that get into ecosystems and what are the impacts?

Terrestrial vertebrates and birds

i) Ecotoxicology.

I will use the example of brodifacoum ecotoxicology to show how an environmental contaminant can quickly spread throughout the food web. Brodifacoum was used in North Island podocarp forests to control possums and rats following the discovery of kokako during the 1980s. This control was expedited with baits that contained 20ppm brodifacoum (i.e., 0.002% wt/wt). It was placed in bait stations so there was negligible interference by birds. The bait was effective at controlling target pests, including all stoats, weasels, and ferrets that died from eating dead rats and possums (i.e., secondary poisoning). It soon became apparent this form of control was also killing other non-target species with bird deaths increasingly noted, and especially raptors (owls and Falcon) as apex predators. Monitoring of bird mortality demonstrated up to 50% of morepork, 70% of falcon, and 40% of weka were killed at some locations, along with other species (harrier hawk, black-backed gulls, kea, kaka, short-tailed bats, long-tailed bats, etc, etc). The brodifacoum went right through the food web. At these sites with thousands of bird deaths, I estimate only 8kg of active ingredient went into the ecosystems. Why was it so insidious? Three reasons. The persistence of the material in tissue (half-life in liver=114.6 days), the fact that when it gets into blood it binds to protein where blood is being filtered (liver, kidneys, placenta), the fact that it bioaccumulates, and the fact it is so effective at interfering with enzyme systems in the vitamin-K cycle.



Fig, 17. Some of the species in the food web poisoned through secondary & tertiary poisoning by brodifacoum.

Let us now look at PFAS and metal halides as they enter the food web. PFAS and metal halides have very long half-lives (see Table 1 above) and so they bioaccumulate in vital organs (liver, kidney, and placenta). Of the metal halides that bioaccumulate, zinc, cadmium, lead, manganese, and aluminium are the most persistent and most long-lived. They too bind to tissue where blood is being filtered (liver, kidney, placenta) for very long periods and bioaccumulate. Then in amongst a raft of molecular processes and enzyme actions, these 5 very persistent compounds disrupt normal physiology, and cause long-term health impediments. The similarities between brodifacoum and metal halides / PFAS are remarkable; except at the site of the solar farm the amount of 'forever chemicals' leached into the environment will be 3-orders of magnitude higher than the amount of brodifacoum that went into the environment within North Island podocarp forests. What are the exposure routes for birds? There are many that include bioaccumulated residues in earthworms, residues in blackberry, residues in rosehip berries, residues in nectar, residues in slugs and snails, residues in invertebrates feeding on flowers, residues in seeds, residues in plant roots (e.g., eaten by the porina grub that is then eaten by frogs and insectivorous birds once it metamorphosises into a moth), residues in plant stems, residues in leaves (eaten by insects that are then eaten by fantails) residues in rodents that feed on seeds and are then eaten by raptors (owls and hawks).....and it goes on and on just as was the case with brodifacoum until we have PFAS and heavy metals spread far and wide. What are the impacts? Birds' eggs are less viable (Monclus *et al.* 2020), hatchlings have poor survivorship, fewer birds are fledged, longevity of adults eating contaminated foods is reduced (Espin *et al.* 2016), the immune systems of birds are compromised (Bichet *et al.* 2013), impacts on DNA change birds morphologically (Albayrak *et al.* 2021), there is nephrotoxicity, hepatotoxicity, impaired growth, and believe me for each class of terrestrial vertebrates the list goes on and on. Offshore it is the subject of hundreds of research papers. Heavy metals and PFAS entering the food web are a significant catalyst to ecosystem impacts and the loss of biodiversity. We give two examples below.

Example 1.

In the section on uptake by plants we noted that blackberry bioaccumulated lead (Pb^{2+}) in fruit until it contained 29x the accepted concentration for berries (Vlad *et al.* 2019). Rosehip berries at contaminated sites in Croatia (Zeiner *et al.* 2018) contained on average 8,242 mg/kg of aluminium (Al), 11.3 mg/kg of nickel (Ni) and 3.34 mg/kg of lead (Pb). Small passerines (e.g., blackbirds) eat these berries and ingest toxic doses of heavy metals. In a study comparing lead (Pb) at control sites in rural areas with those in contaminated urban areas (Roux *et al.* 2007), it was established that passerines and other fruit-eating species at contaminated sites contained 3-5x the blood lead that birds at control sites contained (Fig. 19). Mortality of birds containing high concentrations of metal halides is high, fertility is impaired, and behaviours are changed.

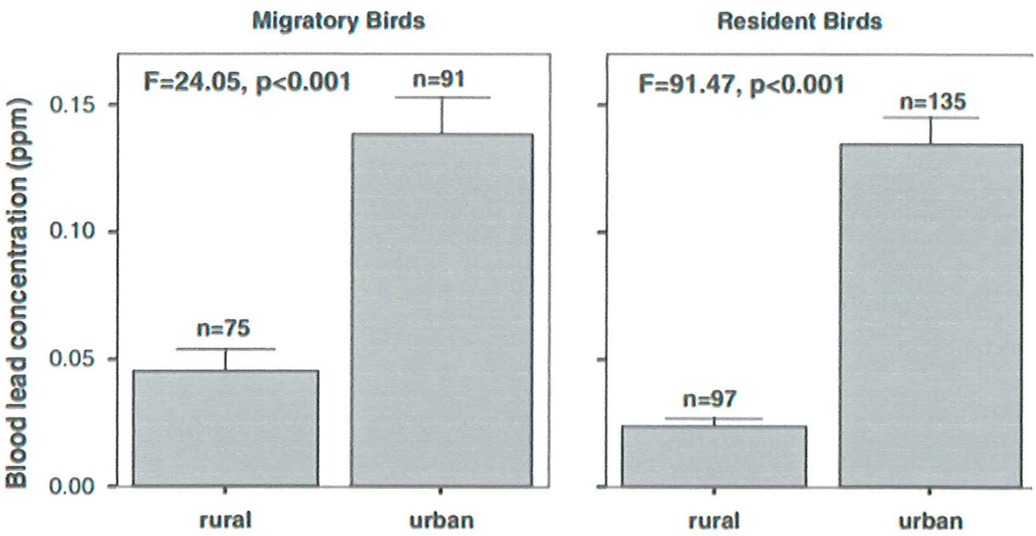


Figure 19. Lead in the blood of birds at contaminated urban sites and in rural areas (Roux *et al.* 2007).

At Brookside blackberry and rosehips grow wild, suggesting that the many berry-eating birds in the district are going to ingest elevated levels of metal halides from the proposed USSP-facility. If these birds are predated by domestic cats, then inevitably pets occupying the homes of residents will be impacted by secondary poisoning with heavy metals. These things are not just a possibility but are an inevitable long-term outcome of siting solar panels in a community that has animals at their heart.

Example 2.

Bird mortality at solar farms often relates to bird impacts with solar panels. Extensive studies have demonstrated that around 10.5 birds hit solar panels and die per megawatt of electricity produced per year (Walston *et al.* 2016).

This suggests a 160MW site will kill 1680 birds per year or around 58,800 birds in the 35-year timeframe of the project. The reasons for this high avian mortality remain unclear, just as avian mortality by birds striking household windows remains unclear. None-the-less, in the course of this project almost 60,000 birds will die by hitting solar panels.

The impacts of solar panels at Brookside on birds will have a HSNO classification of 9.3C.

Aquatic organisms (waterfowl and fish)

It is inevitable that a large portion of leachates on land will run-off into drains and waterways that go down to Te Waihora (Lake Ellesmere). Once in the lake they bioaccumulate within that ecosystem. It has already been demonstrated that heavy metals and PFAS in solar technologies are highly toxic to aquatic organisms *(see* Hazards). Furthermore, we can see in Table 1 above that all the components of solar technologies have a HSNO classification for aquatic organisms, with most listed as 9.1A or 9.1B substances.

Many metal halides, and especially Pb^{2+}, Ag, Cr, Cd, Cu, Al as common USSP leachates are very toxic to organisms that live in surface waters (all are classified as 9.1A substances). All the PFAS are also highly toxic to aquatic organisms, derivatives from combustion of PFAS are toxic to fish, many of the iodides present in solar technologies are toxic to aquatic organisms, and finally hydrogenated fluorides (from burning PFAS) are very toxic to aquatic organisms. Silica in the form of finely ground granules gets into the gills of fish (Book *et al.* 2019 & 2021) resulting in toxic effects that impair respiration (HSNO=9.1B for very fine granules, or 9.1C for slightly coarser granules of silica). This impact on aquatic organisms cannot be dismissed in the risk assessment to creeks and Lake Ellesmere, because silica leachates are a big leachate from solar panels.
If we focus on lead, then the leachates from solar panels were 0.28-4.37 mg/L at solar facilities, and the EC_{50} for fish embryos containing these leachates was 26% at 7 days, and the EC_{50} for water fleas was >50%. Kwak et al. found that PbI2- treated zebrafish and Japanese medaka exhibited multiple adverse effects (e.g., growth reduction, tail malformation, spine deformity, haemostasis, and oedema deformation in organs) with increasing PbI2 exposure concentration from 1 to 20 mg /L. Bae et al. compared the toxicity of perovskite MAPbI3 to four ecotoxicity species, where the order of their ecotoxicity *was D. magna>D. rerio>C. elegans>C. riparius.* Based on *C. elegans* in 72 h reproduction, the mean EC50 values were 0.59, 5.05, 2.65, and 4.30 mg/L for Pb2þ, PbI2, PbO, and PSC, respectively. Liu et al. reported that *S. obliquus* growth was remarkably inhibited when the initial MAPbI3 leachate level (CPL) was above 40 mg/L; and when the CPL was over 5 mg/L, and the survival of *D. magna* was notably threatened. The 72 h EC_{50} of *Scenedesmus obliquus* (phytoplankton) was calculated as 37.21 mg/L, and the 24 h LC_{50} of $Ch_3NH_3PbI_3$ from solar panels to *D. magna (*water flea*)* adults and neonates were calculated as 37.53 and 18.55 mg/L respectively (Liu *et al.* 2021). All this research suggests that leached Pb at USSP-facilities induces high toxicity to aquatic organisms even at low concentrations. The aquatic toxicity of other substances like hydrofluoric acid, phosphoric acid, hydrogen cyanide, hydrogen fluoride, other metal halides, etc from fire and combustion products at solar farms are all listed with a 9.1A hazard classifications (i.e., they are all highly toxic to aquatic organisms).

Also of concern are the impacts of contaminated fish containing metal halides and PFAS on other species in the food web that eat them, including man. Birds that feed on aquatic organisms are affected by metal halides and PFAS (see above). Recent research out of America demonstrates that PFAS in a single fish harvested from freshwater present more of a risk to that person's health than that person drinking PFAS contaminated water for a month (Barbo *et al.* 2023). The reason for this is that fish bioaccumulate PFAS over a period of time in contaminated ecosystems and that concentrate of hazardous substances is then eaten by humans.

In a study where freshwater fish were harvested from relatively "clean ponds" and then exposed to 'contaminated waters' (Vinodhini *et al.* 2008) it was found that lead (Pb), cadmium (Cd), Nickel (Ni), and chromium (Cr), which are all common metal leachates from solar farms, progressively increased in gills (Fig. 1), liver (Fig 2), kidney (Fig. 3) and flesh (Fig. 4). These concentrations of cadmium and lead in gills affect fish health (Shahid *et al.* 2022). In other research the high concentrations of aluminium in the gills of fish when water pH was below 6 was sufficient to kill them. The amounts of toxic metal halides, PFAS, silica, and iodides as leachates when combined with fluoride derivatives, hydrofluoric acid, and other assorted toxicants produced in a fire present a significant risk to the endangered mudfish (*Neochadda apoda*) that reside in surface waters along Buckleys Road and Caldwells Road.

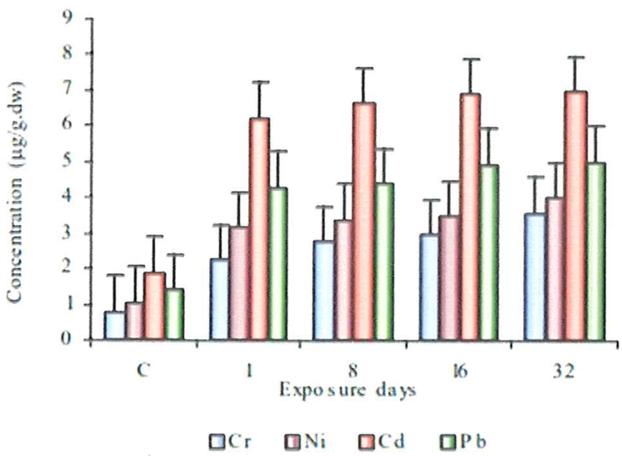


Fig. 1: Accumulation of heavy metals in gills

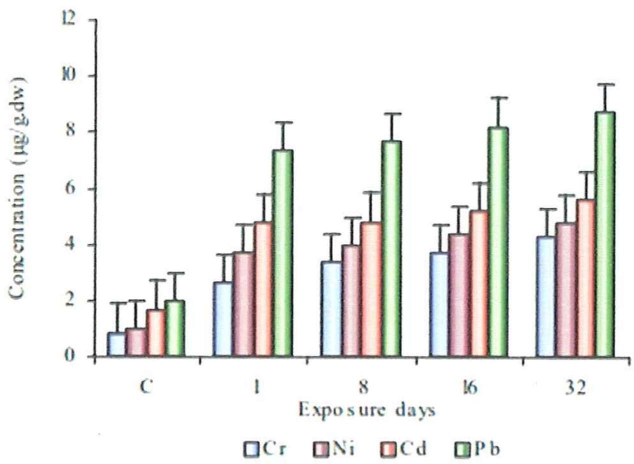


Fig. 2: Accumulation of heavy metals in liver

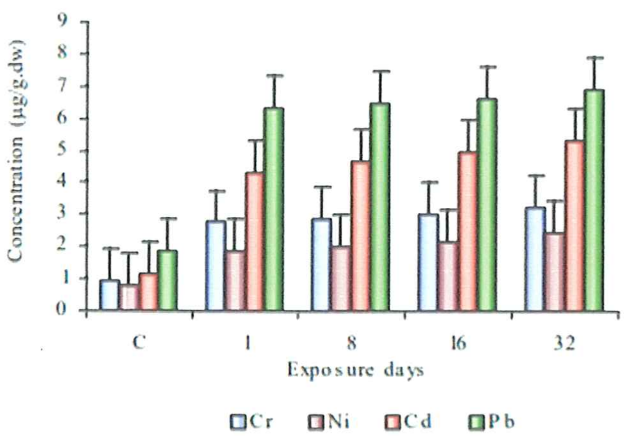


Fig. 3: Accumulation of heavy metals in kidney

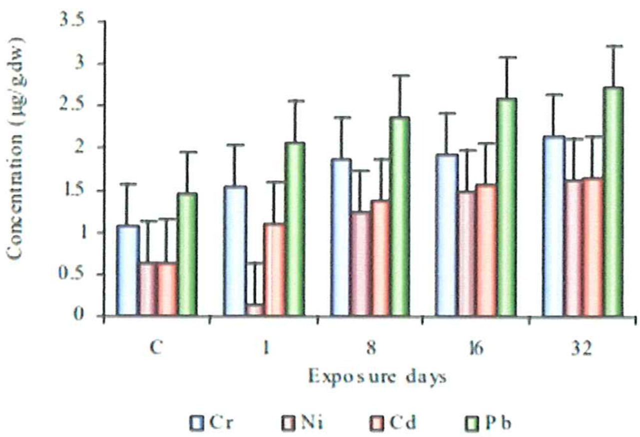


Fig. 4: Accumulation of heavy metals in flesh

So how much leachate will run off the proposed site for the solar farm? There are three modes of transport: in dust which in China and India is a significant medium for moving heavy metals and PFAS; in smoke in the event of a fire, and in water. In light rains almost all moisture is soaked into soils. However, in heavy rains run-off at the site is huge. The site is after all a flood plain, so water runs into channels and down into drains alongside Buckleys Road and creeks alongside Caldwells/Hanmer Roads (see Fig 19 below).

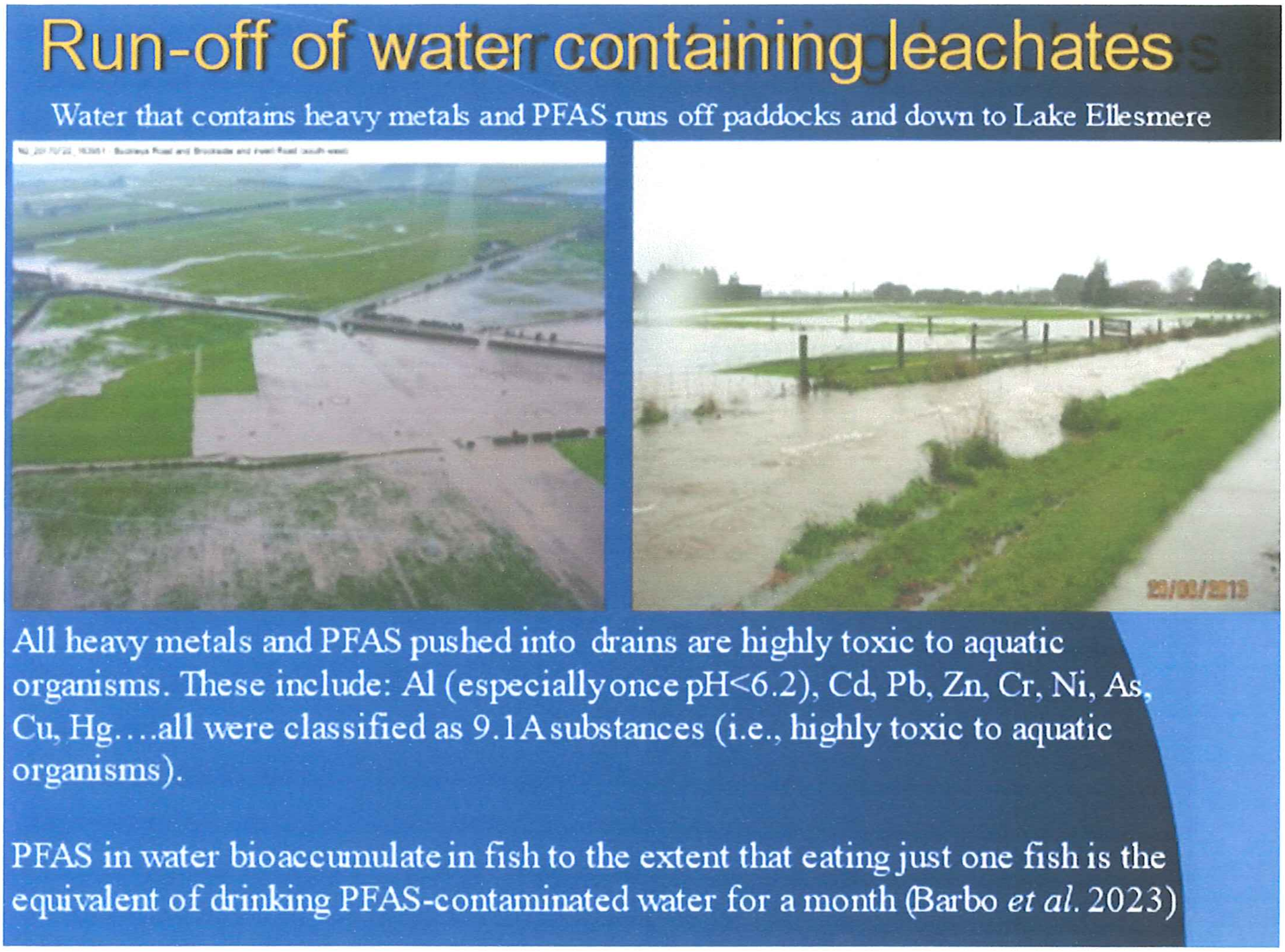


Figure 19. **Top left shows the intersection of Buckleys and Caldwells Roads, with water flowing in channels into the Caldwells Drain. Top right is flood waters draining into Caldwells Drain.**

We cannot locate a meta-analysis of the impacts of leachates from solar technologies on waterbirds. However, what we can provide is an example of how the 'forever chemicals' affect the food web of one species of bird. In India where the land and soils are extensively polluted with heavy metals, these flow down in streams to Lake Veeranam, where they bioaccumulate in crabs, prawns, and other biota (Table 11 below) at concentrations that exceed WHO guidelines for food (Pandiyan *et al.* 2022). The metals that most impacted this ecosystem were arsenic chromium, and lead.

Table 11. Metal accumulation in various prey species of waterbirds, Veeranam Lake, Tamil Nadu, India (Values are mean and SE; ppm).

Metals	Crabs (N = 6)	Prawn Species (N = 6)	*Claris batrachus* (N = 6)	*Mystus vittatus* (N = 6)	*Cyprinus carpio* (N = 6)	*Labeo rohita* (N = 6)	*Tilapia mossambica* (N = 6)	*p* Value
As	5.58 ± 0.029	2.06 ± 0.06	13.04 ± 0.038	1.79 ± 0.036	2.45 ± 0.378	2.29 ± 0.298	0.43 ± 0.002	$p < 0.001$
Cr	1.81 ± 0.039	0.34 ± 0.010	9.70 ± 0.100	5.75 ± 0.142	3.02 ± 0.112	0.85 ± 0.079	0.35 ± 0.004	$p < 0.001$
Cu	3.60 ± 0.190	2.49 ± 0.186	1.83 ± 0.052	0.51 ± 0.015	0.11 ± 0.029	0.12 ± 0.008	0.008 ± 0.003	$p < 0.001$
Pb	8.48 ± 0.234	5.56 ± 0.171	4.86 ± 0.103	2.61 ± 0.107	6.88 ± 0.108	5.74 ± 0.073	5.76 ± 0.056	$p < 0.001$
Hg	0.05 ± 0.0006	0.13 ± 0.064	0.28 ± 0.072	0.10 ± 0.004	0.10 ± 0.047	0.05 ± 0.031	0.01 ± 0.004	$p < 0.001$
Ni	2.43 ± 0.039	0.50 ± 0.017	5.03 ± 0.027	0.79 ± 0.088	1.18 ± 0.383	0.23 ± 0.028	0.91 ± 0.024	$p < 0.001$
Zn	2.99 ± 0.006	1.34 ± 0.032	3.68 ± 0.092	2.82 ± 0.091	2.73 ± 0.120	1.70 ± 0.095	1.86 ± 0.059	$p < 0.001$

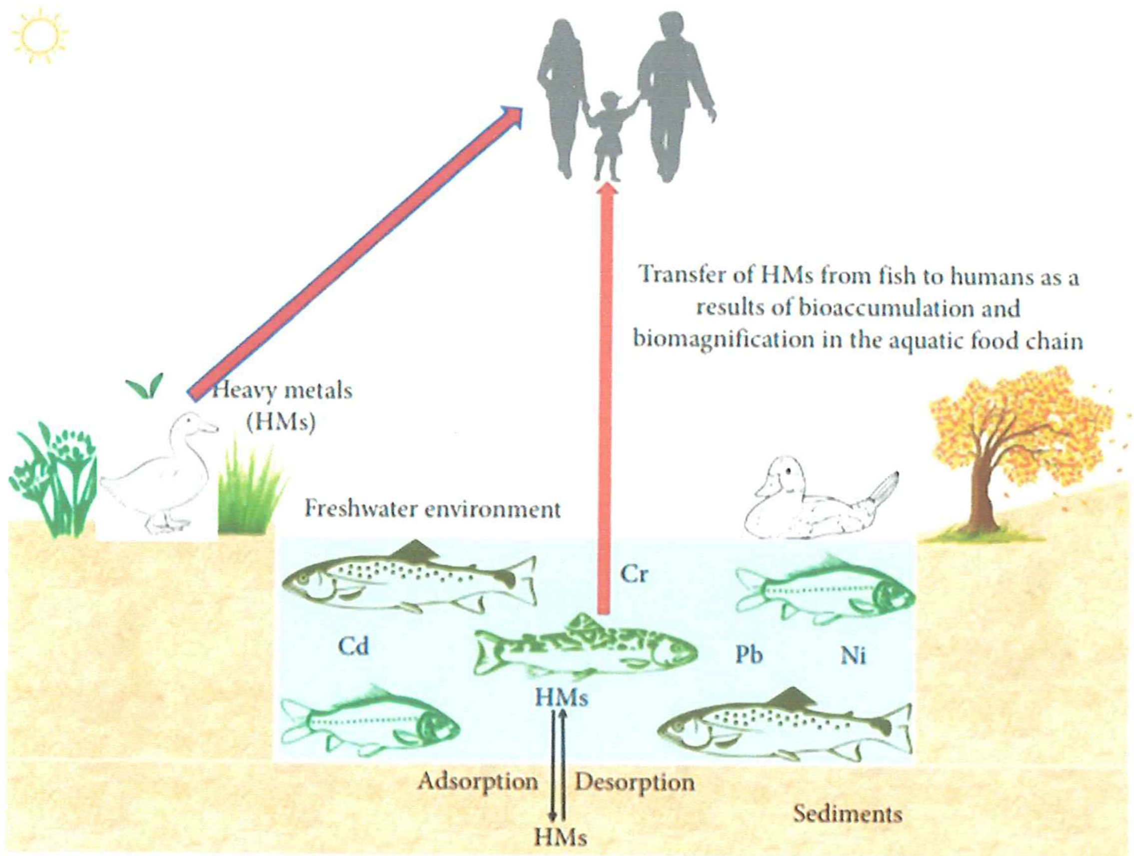
The herons that feed on aquatic organisms at the lake then ingest heavy metals as part of their diet on prey species, and these heavy metals then bioaccumulate in the birds (Table 12 below). Unsurprisingly, the chemicals most prevalent in the herons were arsenic, chromium and lead. If you pollute an environment with heavy metals, those same heavy metals become prevalent in birds. These concentrations of heavy metals affect bird fertility, bird behaviour, bird health, and the longevity of affected birds. This contributes to species decline and ultimately compromises the vigour and health of ecosystems.

Table12 Level of metals in the different organs of the black-crowned night heron, Veeranam Lake, Cuddalore, District, Tamil Nadu [Values are mean and SE; ppm (N = 3)].

Metals	Tissue	Kidney	Liver	Feather
As	1.92 ± 1.46	3.04 ± 0.31	2.63 ± 0.04	0.43 ± 0.007
Cr	0.72 ± 0.004	1.62 ± 0.13	6.98 ± 0.10	2.25 ± 0.09
Cu	0.54 ± 0.03	0.15 ± 0.08	0.51 ± 0.01	0.84 ± 0.63
Pb	5.39 ± 0.03	4.07 ± 0.69	5.63 ± 0.08	5.53 ± 0.05
Hg	0.01 ± 0.003	0.15 ± 0.13	0.04 ± 0.01	0.02 ± 0.007
Ni	0.54 ± 0.03	0.16 ± 0.08	0.57 ± 0.02	0.63 ± 0.08
Zn	1.26 ± 0.02	0.23 ± 0.08	1.41 ± 0.01	0.92 ± 0.01

We could have chosen thousands of other examples but have used this one. Essentially the same thing will happen at Brookside, with metal halides and PFAS washed off the USSP site in heavy rains and down the creeks to Lake Ellesmere. The herons and other waterbirds feeding there will be ingesting 'forever chemicals', many of which can be sourced back to the Brookside solar panels.

In his publication on the ecotoxicology Ali *et al.* presents a visual summary of the transfer of heavy metals to humans.



: Trophic transfer of heavy metals from freshwater fish to humans in the human food chain

Bioaccumulation of 'forever chemicals' presents a serious problem in aquatic systems and is a medium for transfer of these hazardous substances to communities that harvest 'wild foods' from Lake Ellesmere (e.g., Māori).

The impact of solar farm leachates on aquatic organisms is 9.1B.

Summary

The information on residues from metal halides and PFAS does not portend well for New Zealand's image of "100% pure" and a land with a "clean-green environment" that politicians like to portray. Why does New Zealand have issues with deteriorating environmental standards? Quite simply, we have policy directions from government that do not mesh well with the provisions of the RMA 1991 to protect our environment and our health and safety. The plethora of recent literature on e-waste, heavy-metals and PFAS as contaminants in food, indicates these things have become a serious issue in overpopulated nations throughout Asia and Africa. We have presented documented evidence that these things are now a major issue affecting the health and wellbeing of all people, but more especially babies and infants. Babies are now born in China with poor AGPAR scores, poor physical attributes (height, head circumference, chest circumference, BMI), and poor states of cognition because heavy metals (Pb, Cd, Ni, Al, and Ag) and PFAS from the electronics industry have passed through the placenta into the unborn foetus. These problems are exacerbated in breast-fed babies where PFAS and heavy metals are expressed in breast milk and add to the burden of 'forever chemicals' within the infant. Cow's milk in these nations is not an alternative because that milk is also polluted by heavy metals and PFAS (e.g., Muhib *et al.* 2016). In these polluted nations we cannot identify where all pollutants come from, but China with the highest level of pollution from the electronics industry singularly has more solar technologies generating electricity than any other nation on Earth.

The people of Brookside DO NOT WANT SOLAR TECHNOLOGIES in their locality for particularly good reasons. This has happened through a lack of consultation with the community by the applicant, Boffa Miskell, Selwyn District Council and ECan. It has happened through a lack of due diligence on environmental standards, an obsession with fast-tracking the consent via a process of 'limited notification to 4 neighbours', and through potential 'conflicts of interest' during the vetting of compliance. I can almost guarantee that Environment Canterbury and Selwyn District Council have no more insight into the types of solar technology and methods to be used in the project than 'notified parties'. How many building consents does SDC approve where they do not know whether the building will be brick, concrete, wood, or steel? How many building consents are approved by the SDC where there is no 'schedule of works'? How many building consents are approved where there is not a list of certified materials in the application? How many building consents are approved where there is no approved landscaping design? How many building consents are approved where the planned building is going to emit 50 decibels of noise from its air conditioning in a residential area? How many building consents are issued where the contractor has no oversight of waste disposal? Furthermore, we can state with some degree of certainty that not one person through the whole saga of adopting solar technologies has done a thorough review of the environmental and health consequences from this form of electricity generation. If they had, I cannot find that review after hours of searching the MPI, NZFSA, MfE, or ERMA websites. Someone should have done a systematic review and undertaken due diligence of risks before adopting policies to use solar technologies throughout New Zealand. If they had, we could state with certainty they would identify huge 'information gaps' that need to be explored before USSP facilities are widely adopted. In our view the implications of what is proposed for the environment, health, trade, and public wellbeing are totally unacceptable.

We are not able to challenge government policy settings, but within the bounds of what is bookended by the Local Government Act 2002 and the Resource Management Act 1991, we as the "local community" have a right to have a have a say as to what are unacceptable risks for the Brookside community. As residents we can state with some degree of alacrity that what is contained within the application by KeaX Ltd for resource consent is not what we want in our neighbourhood; it presents an unacceptable risk to not only the soils, water, air, and ecosystems at Brookside, but the health and welfare of people that live in the area. We understand the applicant has the financial resources to go through litigation and to contest decisions within the court system, and that he has money that in essence will "buy justice" for him. What none of that does is mitigate against the unacceptable risks he is presenting to Brookside residents and their environment.

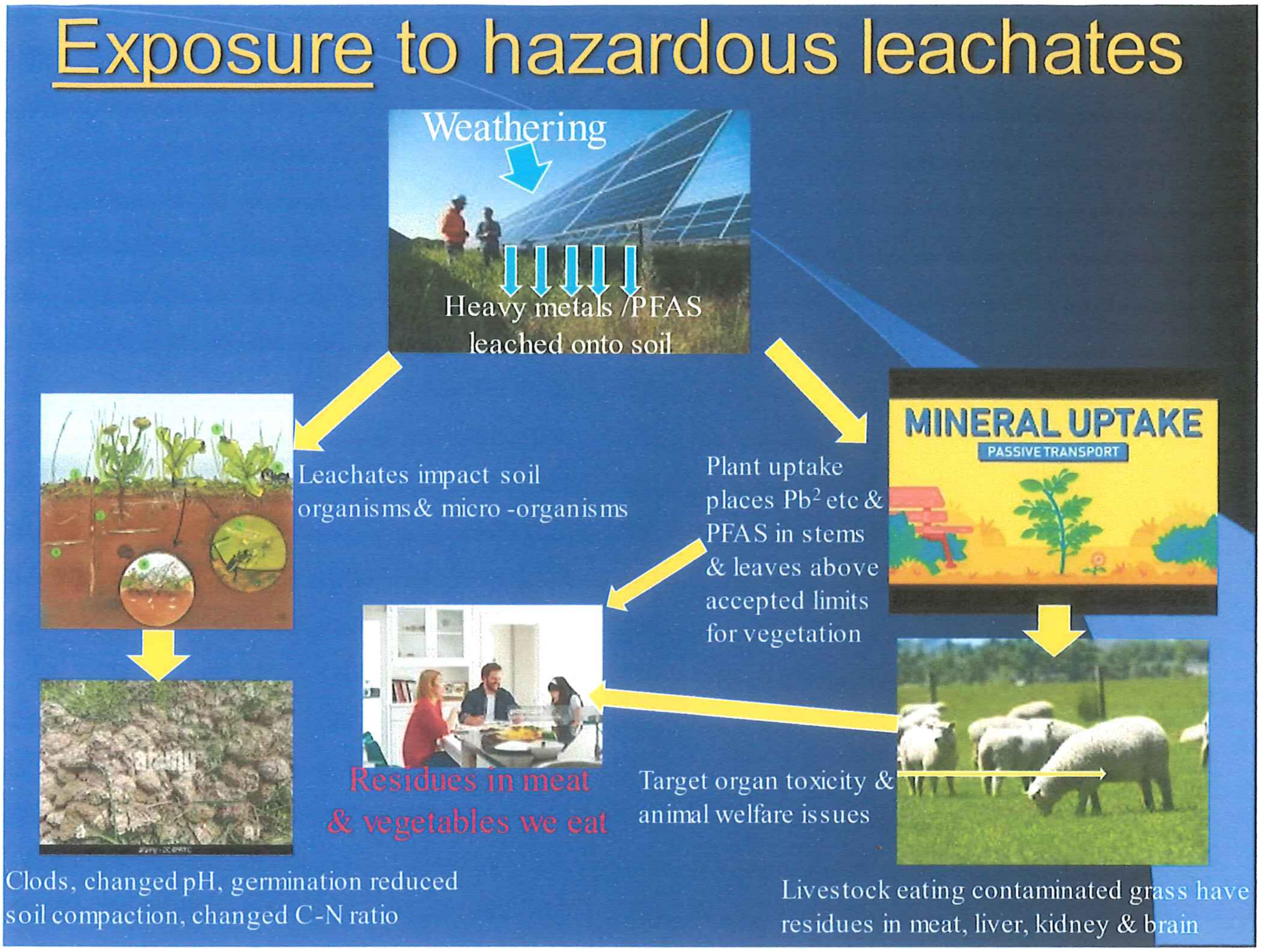
The application does not comply with the RMA 1991. We have identified that the 'forever chemicals' associated with solar technologies when combined with existing electrical waste, will progressively contaminate drinking water as has happened offshore; we have identified that 'forever chemicals' leached onto soils are not only toxic to soil organisms and soil micro-organisms (9.2B) but change the nature of soils; we have identified that 'forever chemicals' are taken up by plants and bioaccumulate in plant roots, plant stems, plant leaves (all 6.9B), and that they contaminate plant nectar (i.e., honey); we have identified that 'forever chemicals' ingested by herbivores eating contaminated plants or drinking contaminated water have the capacity to bioaccumulate heavy metals and PFAS in the livers, kidneys, hearts, brains and placentas of animals thus creating issues of target organ toxicity and animal welfare (9.3C); and we have established that meat by-products, vegetables, and water contaminated by 'forever chemicals' may in the future not only exceed international guidelines set by WHO and the European Commission but severely incapacitate people as it has done to those living in India, China, Pakistan, Bangladesh and Nigeria through 'target organ toxicity' (6.1C). Research has demonstrated that many of the 'forever chemicals' associated with USSP facilities are reproductive and/or developmental agents (6.8B), carcinogens (6.7B), and we have demonstrated that some of these 'forever chemicals' are mutagens (6.6B). We have identified that the 'forever chemicals' from USSP facilities will enter the food web of aquatic organisms and impact the endangered mudfish alongside the site (9.1C), impact terrestrial vertebrates and birds (9.3B), and terrestrial invertebrates (9.4C). The effects on animal fertility, animal welfare, and animal behaviour all compromise the local economy, biodiversity, and ecosystem stability.

So, why are the implications of using solar technologies so pervasive? Quite simply because solar technologies are made almost entirely of 'forever chemicals' that bioaccumulate in the food web. No-one eating contaminated food or drinking contaminated water ingests harmful amounts within a day, a week, or a month; but when they ingest chronic doses over a year or more, they experience 'target organ toxicity'. This phenomenon is called sub-chronic toxicity. The research out of China demonstrates these 'forever' heavy metals and PFAS are found at high concentrations in the placentas of many pregnant women. Babies are born with errant AGPAR1 scores, which show they are distressed right from the time they inhale their 1st breath, and they subsequently suffer a range of physical and mental impairments throughout life. The early years of noncognitive and cognitive development in infancy are difficult, because with a small body mass a child inherently has a high loading (mg/kg) of PFAS or metal halides that progressively increase because 'forever chemicals' are expressed in mother's milk. The cognitive abilities of some children in China are impaired, some noncognitive processes that affect behaviours and emotions are not fully developed, the infant is shorter, has a smaller head circumference, and is disadvantaged from an early age. By the end-of-life, everyone in India, Pakistan, Nigeria, and China has ingested a sub-lethal quantity of Al, Pb, Cd, Zn, Ni and a range of PFAS that are embedded in their livers, kidneys, cardiac tissue and most importantly within their neurological systems. Aluminium and Pb^{2+} are neurological toxicants that cause Alzheimer's, dementia, and limit the ability of the elderly to control voluntary muscles. Do we really want a contaminated site in Brookside?

Some may say what is happening in China and India with e-waste, heavy metals and PFAS does not concern us. Under normal circumstances I would agree, but unfortunately the applicant wants to park a USSP-facility with thousands of tonnes of these 'forever chemicals' over the fence from our properties. He cannot assert that the consequences are "MINOR" because we have provided a plethora of literature published in peer reviewed science journals stating that it is having "MAJOR" impacts on soils, water, and air. That foot high pile of literature includes the impacts of heavy metals and PFAS on flora and fauna, the impacts of these 'forever chemicals' on ecosystem health and demonstrates their impacts on aquatic systems. These things have all been detailed in the sections above.

Those that have worked in the industry for decades know the risks. Kwak et al. in his 2021 publication states: "to date, the development and improvement of PV technologies has received substantial attention; however, their potential environmental risks remain unknown. Therefore, this review focuses on the potential risks of leachates derived from solar cell devices. We collect scientific literature on toxicity and leaching potential, tabulate the existing data, and discuss related challenges. Insufficient toxicity and environmental risk information currently exists. However, it is known that lead (PbI2), tin (SnI2), cadmium, silicon, copper, and aluminium which are major ingredients in solar cells, are harmful to the ecosystem and human health if discharged from broken products in landfills or after environmental disasters. Several research directions and policy initiatives for minimizing the environmental risks of PV technology are suggested." Zhang *et al.* in his 2023 publication (viz. hot off the printing press) states "PV solar technology is not free of adverse environmental consequences such as biodiversity and habitat loss, climatic effects, resource consumption, and disposal of massive end-of-life PV panels". Both these men make their bread and butter from solar technologies and know its benefits and shortcomings inside out. Do they sound assured that the risks are only MINOR? Zhang's paper in fact is titled "Green or Not?"

A slide from a recent presentation to the Brookside community summarize "RISKS"



In deciding whether to approve the RMA application, the assessors at the meeting on the 23rd February must appropriately balance risks (i.e., hazards x exposure) with the directives from what I believe is yet another poorly conceived government policy. I began this dissertation with the examples of cadmium in superphosphate, and nitrates from dairy intensification in drinking water. Both those environmental disasters happened in New Zealand as a result of ill-advised "government policy". We have provided enough evidence that solar technologies are yet another ideology for productive farmland in the New Zealand landscape that may have serious consequences for our environment. For the Brookside community it is a travesty of huge proportions. We live on fertile soils that should be providing export earnings; not generating electricity that potentially creates a 'contaminated site' and only benefits foreign investors and self-serving investors. We are the guinea pigs in the machinations of "get-rich-quick schemes" and "quick-fix band-aids" for infrastructure shortfalls in electricity. The "hazards" within solar technologies (i.e., heavy metals and PFAS) are "high" and levels of "exposure" by Brookside residents are "more than minor". Therefore, "RISKS" in the form of RISK=HAZARD x EXPOSURE are also MORE THAN MINOR. We are not talking semantics and hypotheticals, but FACTS from science literature published in peer-reviewed journals. These are real risks that currently confront the peoples of China, India, Pakistan, and Africa. Within 20 years as solar panels delaminate and weather, those risks will also be a reality here in New Zealand, and more particularly a reality for the residents of Brookside. The RMA is supposed to mitigate against those risks. Somehow, the system has failed the local community at Brookside, and they have been put through a council ringer to enable the applicant to gain compliance for an enterprise that is thwart with political shortcomings, fiscal and economic shortcomings, regulatory shortcomings, environmental shortcomings, and shortcomings for the health and welfare of the Brookside community.

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